GOVERNMENT OF KARNATAKA

GANESH

SCIENCE

Part II—BIOLOGY

X STANDARD

(Revised Edition)

NATIONAL ANTHEM

Jana gana mana adhinayaka, jaya he
Bharata bhagya vidhata
Punjaba Sindhu Gujarata Maratha
Dravida Utkala Banga
Vindhya Himachala Yamuna Ganga
Uchchhala Jaladhi Taranga
Tava subha name jage,
Tava subha asisa mage,
Gahe tava jaya gatha.
Jana gana mangala dayaka, jaya he

Ceejay. 1994

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(D.S.E.R.T. Text Book Division)

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PREFACE

Science curriculum in High Schools has to be continually adapted due to explosion in our scientific knowledge and newer methods of presentation of subject matter. The faculty of the Indian Institute of Science as well as the Directorate of Text Books, Government of Karnataka is concerned with this problem. Based on mutual discussions, the revision work of Science and Mathematics textbooks for 8th, 9th and 10th standards of the Stae was taken up. The revision was done after continued discussions with many teachers from the city as well as rural areas.

The Present revision has been carried out within the framework of the existing syllabus. Attempts have been made to improve the presentation of the material in a manner for easy comprehension and understanding. Such efforts have resulted in the restructuring and rewriting of a number of chapters, providing newer information, addition of a few figures and deletion of mistakes and errors. Foot-notes and activities have been added in a few places. While this does not form a part for the purposes of examination, it is hoped that these will stimulate the teacher and the student. It is not our claim that the present textbooks are devoid of typographical and other errors. We recognise that there may be some inaccuracies and we will only be too happy to welcome comments and suggestions to improve the textbooks. The syllabi have been retained throughout as before and no topics are either sacrificed or added. It is, of course, absolutely necessary to have a relook at the syllabi and reprepare the textbooks so as to make them model textbooks.

Any venture of this type needs co-operation and support from many for successful completion. I have been fortune in this direction by having the ablest assistance of Dr. V. Krishan, Dr. S. Mahadevan and Dr. V.G. Tikekar in the branches of Chemistry, Biology and Mathematics, respectively. Financial and other assistance in this work was provided by Karnataka State Council for Science and Technology. Indian Institute of Science (Centre for continuing

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CHAPTER 1

Transport System in Animals

The life activities of an organism need a constant supply of oxygen and food and the elimination of waste products. The life activities involve a number of chemical reactions. Some of these reactions constantly make the body substance and some constantly break them down. The sum total of all the chemical changes which take place in the organism is called *metabolism.* A number of enzymes are involved in metabolic processes. Metabolism is a continuous process and is necessary for the existence of the organism. If metabolism stops, all life activities will cease.

In amoeba and hydra, cells are in direct contact with the external medium (water). They obtain oxygen and eliminate waste products including carbon dioxide by diffusion. Digestion of food is intracellular in amoeba. The digested food is circulated in the cell body by the movement of protoplasm. In hydra, digestion is both extracellular and intracellular. The digested food diffuses into the ectoderm from the endoderm. In larger animals many tissues are located at a distance from both the external and the digestive surfaces. The function of supplying nutrients and oxygen, to and the removal of metabolic waste products including carbon dioxide from the tissues and organs is performed by the *circulatory* or *transport system.* The circulatory system also helps in carrying chemical messengers such as hormones from one part of the body to the other.

Transport system or *circulatory system* consists of a circulating fluid such as blood, lymph or haemolymph (blood of cockroach) flowing in definite vessels or body spaces (cockroach).

Human blood constituents and functions

Although blood appears to be a homogeneous crimson fluid as it pours from a wound, it is composed of a yellowish liquid, called plasma, in which floats the *red blood cells* (*erythrocytes*), the *white blood cells* and the blood platelets (thrombocytes), (Fig. 1.1). Plasma is 55% of blood volume while the cells form 45%.

Fig. 1.1. Types of Blood Cells

1. Red Blood Cells (RBC)
2. White Blood Cells (WBC)
3. Blood Platelets
4. Plasma

Plasma is a complex mixture of proteins, glucose amino acids, lipids, enzymes, antibodies, dissolved gase like oxygen, carbon dioxide, salts, nitrogenous waste

like urea and numerous substances in small amounts. The two chief constituents are water (90 to 92%) and proteins (7 to 8%). Though plasma constantly takes up and gives off substances as it passes through the capillaries, its composition remains remarkably constant. Any change in its composition initiates responses in any one or more organs of the body to restore the constituents and bring back the composition to the normal level.

Plasma contains several kinds of proteins, each with specific properties and functions. *Fibrinogen* is one of the proteins involved in the clotting of blood. *Serum albumin* regulates the water content of cells and body fluids. *Serum globulin* which is rich in antibodies provides immunity from various infectious diseases.

Red Blood Cell (RBC)

Most of the blood cells are RBC ; only about one per cent of the blood cells are WBC. The RBC are biconcave discs and reddish yellow in colour. They float in the plasma. The mature mammalian RBC does not possess a nucleus. An elastic frame-work maintains the disc shape and permits the cell to bend and twist as it passes through blood vessels smaller than its diameter. Blood cells move about by the pumping action of the heart. There are, on an average, about 5,400,000 red blood cells per cubic millimetre of blood in an adult. Red blood cells contain *haemoglobin*, the red pigment that gives the cell its colour and is responsible for the transport of oxygen.

In the embryo, the red blood cells are produced in the liver and spleen ; in the adults they are mainly produced in the red marrow of the bone. The average life of a red

blood cell is about 120 days. They are constantly being destroyed and new ones produced at the same rate. If the number of RBC or the haemoglobin content of the RBC becomes deficient a person becomes anaemic. Some types of *anaemia* can be cured by administering vitamin B_{12} or liver extract.

White Blood Cell (WBC)

The white blood cells differ considerably from red blood cells. They are larger than the red blood cells and less numerous. They are nucleated cells. They are produced in the red marrow of the bone along with the red blood cells, in the spleen and in lymph nodes. They are colourless and do not contain haemoglobin. They are irregularly shaped, active and capable of *ameboid* movement, often against the flow of blood. They can also pass between the cells in the walls of the capillaries into the intercellular spaces of the tissues.

There are on an average about 7000 WBC per cubic millimetre of blood in man. Poorly nourished individuals have fewer white blood cells than normal. They usually have a lower resistance to infection and diseases.

The white blood cells protect the body against diseases. The human body responds to infection by increasing the number of WBC in the blood stream. The white blood cells are attracted to the site of infection and engulf the invaders. In the course of their struggle against invading microorganisms numerous white blood cells are killed. They may accumulate in the infected area together with dead tissue cells, bacteria and living and dead white blood cells. All these form a thick yellowish fluid called *pus*.

After the bacteria have been destroyed the lost tissue is regenerated. When the infection has been brought under control the WBC count drops back to normal.

In some tragic cases, there is an uncontrolled production of WBC in the bone marrow or lymph nodes. This condition is known as *leukemia* or blood cancer.

Blood Platelets

Mammalian blood contains *blood platelets* which are irregularly-shaped colourless bits of cytoplasm lacking nuclei. They are about half the size of RBC and are formed by the pinching off of the surface of giant cells in the red bone marrow. They are important in initiating the clotting of blood. Vertebrates other than mammals do not have platelets. Instead, they have spindle-shaped cells that seem to play a similar role in blood clotting.

Clotting of blood

Whenever the blood vessels are damaged, blood flows out and after sometime it clots. How does this happen ? Whenever blood is exposed to air as in a wound, the fibrinogen precipitates into delicate threads called *fibrin*. The remaining plasma is now a clear liquid and is called the *serum*. The fibrin and the blood cells entangled in it form the *clot* from which the serum flows out. Clot prevents the escape of more blood at the site of the cut. Clotting serves to seal off the breaks in blood vessels and prevents the escape of more blood. Otherwise even a small injury would be fatal, because there would be nothing to stop blood from flowing from the body.

Functions of blood

1. Blood distributes digested food to the cells in the body and removes nitrogenous wastes from the cells to the excretory organs.

2. Blood transports oxygen to the cells and brings back carbon dioxide to respiratory organs.

3. Blood carries hormones to the tissues where they are needed.

4. Blood helps the body to defend itself against diseases.

5. Blood maintains uniform distribution of heat in the body.

6. Blood seals wounds by clotting and also stops bacteria and poisons from entering the body through the wound.

There are two types of transport systems in animals. The *open type* where blood flows in modified coelomic cavities and there are no definite blood vessels circulating and collecting blood. The open type is found in arthropods and molluscs.

The *closed type* where blood flows in definite blood vessels and has no connection with the coelom. Blood comes in contact with tissues, only through capillaries. The closed type is found in earthworm and vertebrates.

Transport system of Earthworm

Now let us consider animals which have definite circulatory system such as earthworm, cockroach, fish, frog and man.

Closely observe the body of an earthworm. You can clearly see blood vessels which are red in colour because of the haemoglobin dissolved in plasma. Blood flows in three longitudinal vessels. (Fig. 1.2).

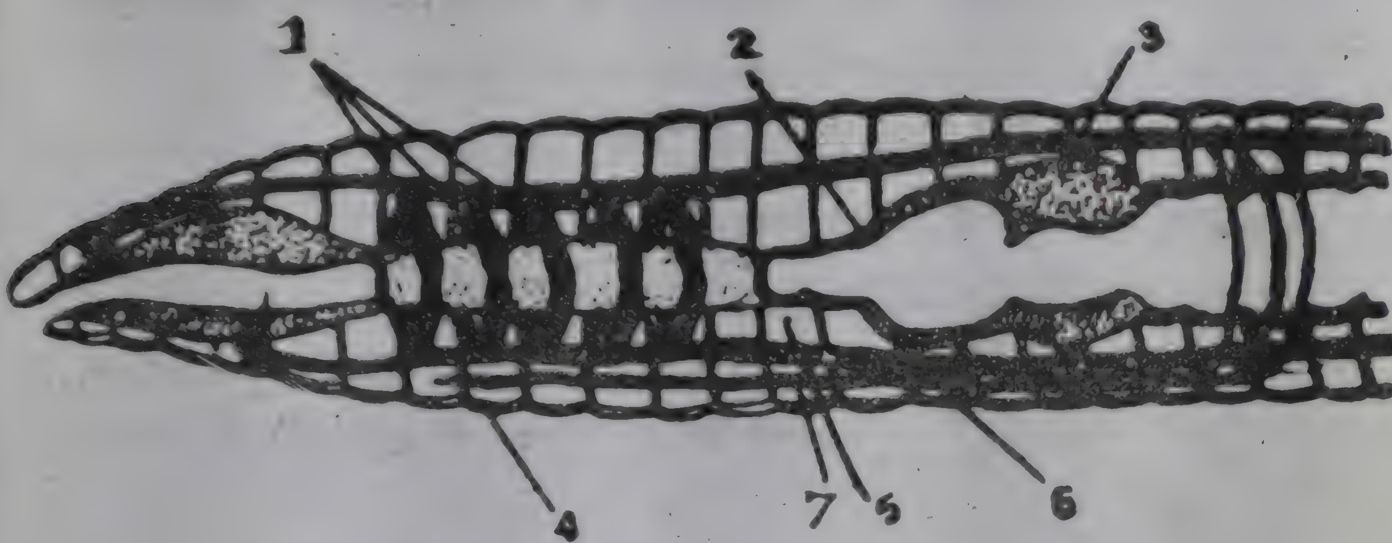


Fig. 1.2. The Circulatory System of the Earthworm

1. Lateral hearts,
2. Wall of the digestive tract,
3. Dorsal blood vessel,
4. Body wall,
5. Coelom,
6. Ventral blood vessel,
7. Sub-neural blood vessel.

The dorsal blood vessel runs above the alimentary canal and collects blood from the intestine, nephridia, skin and so on. Blood flows forwards in this vessel.

The ventral blood vessel lies close to the alimentary canal ventrally and supplies blood to the skin, intestine nephridia and the blood flows backwards. It is the main distributing blood vessel.

The sub-neural blood vessel lies beneath the ventral nerve cord after the 13th segment and is closely attached to the ventral body wall. It collects blood from the nerve cord and skin. It is both a distributing and collecting vessel.

The dorsal blood vessel extends from one end of the body to the other end. By wavelike contractions blood is forced forwards. Blood flows from the dorsal blood vessel into the ventral blood vessel through five pairs of *lateral hearts* surrounding the oesophagus. Numerous branches from both the dorsal and ventral blood vessels distribute blood through the capillary network.

Transport system in Cockroach

The cockroach has an open circulatory system. Blood fills the cavity within the body and covers all the internal organs. The blood-filled cavity is called *haemocoel.* The blood of cockroach is colourless. Its main function is to carry nutrients and hormones around the body and to remove wastes. Blood does not have any role in respiration and it does not contain any respiratory pigment (haemoglobin).

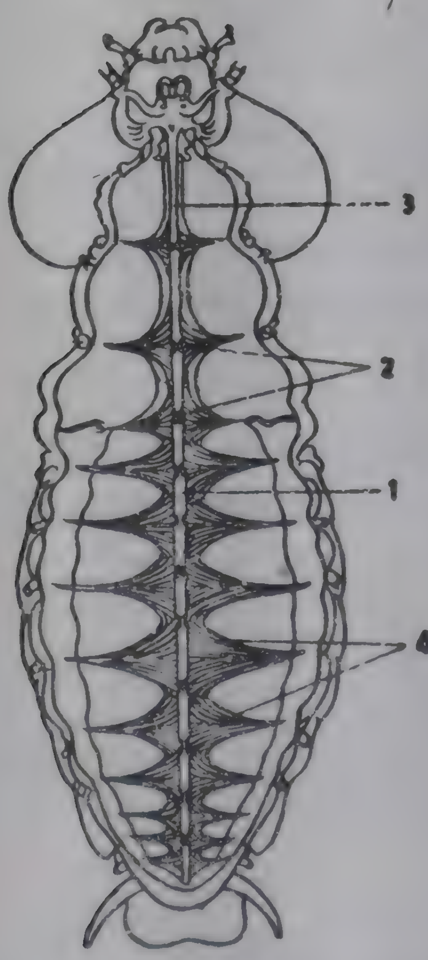


Fig. 1.3. The Circulatory System of Cockroach

1. Heart, 2 Ostia
3 Aorta 4. Alary muscles

How does the blood circulate in the body of the cockroach? The circulation of blood is maintained by a tubular *heart* on the dorsal side below the body wall. The heart is in the form of a tube with paired openings on the sides. It has three pairs of openings in the thorax and ten pairs in the abdomen. Each opening has a valve, so blood can enter the heart

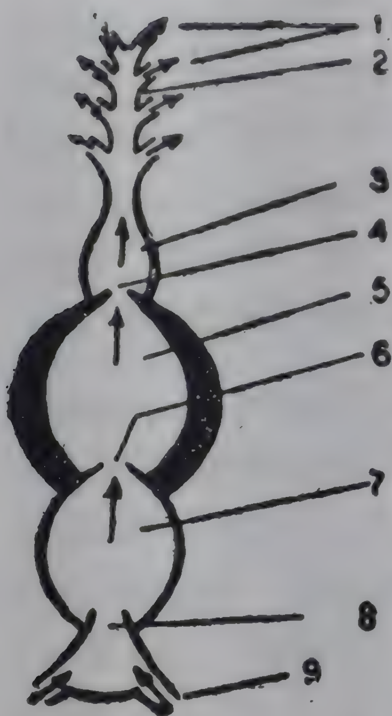
but not leave it through these openings. The rear end of the heart is closed while the front end opens into a blood vessel called *aorta*. The *aorta* branches at the front and one branch goes to the head. Other branches open into other parts of the thoracic region. The blood flows through the tissues and flows back into the body cavity.

A set of muscles called *alary muscles* externally connect the sides of the heart to the body wall. When these muscles contract, the wall of the heart is pulled outwards thereby expanding the heart and creating a suction. Blood now enters the heart through the paired valvular openings. When the muscles relax the heart contracts and blood is pushed forward through the aorta. The contraction of the heart is wave-like, starting from the posterior end and moving anteriorly. Besides the heart and aorta, insects may have *contractile organs* at the base of wings, legs and antennae. Their rhythmic contractions help blood movement in these organs. Body movements also help in blood circulation in the body cavity.

Transport System in Fish

Blood circulation is simple in fish. The heart consists of a straight muscular tube essentially divided into two major chambers, an auricle or atrium and a ventricle. (Fig. 1.4)

Deoxygenated blood, collected from the various parts the body through veins first flows into the auricle and then into the ventricle before entering into the ventral aorta. The venous blood is pumped by the heart through a ventrally located large artery (afferent artery) to the capillaries of the gills where oxygen is taken up and carbon



dioxide released. The gill capillaries then rejoin to form *efferent* arteries and finally give rise to a single artery called dorsal aorta on the dorsal side of the body. Oxygenated blood is transported through the large dorsal aorta to all other tissues of the body via arterial branches and the capillaries, eventually returning to the heart by way of the veins.

Fig. 1.4. The single circulation blood system in Fish.

1. To Gills,
2. Aorta,
3. Artery,
4. Valve,
5. Ventricle,
6. Valve,
7. Auricle,
8. Sinus venosus,
9. Veins from body.

Transport System in Frog

The heart of a frog is somewhat conical in shape and lies ventrally at the level of shoulders, just above the breast bone. It is enclosed by a thin, double walled sac, *pericardium.* The pericardial fluid is present between the two layers of the pericardium. It protects the heart by reducing friction and absorbing shock. The heart has three chambers (Fig. 1.5 AB). Of these, the upper two are smaller, thin walled and are called the right and the left *auricles*. The right auricle is bigger than the left. They are dark coloured The two auricles are separated externally by a groove and internally by a wall. The lower conical chamber, which is larger than the auricles is known as the *ventricle*. It is lighter in

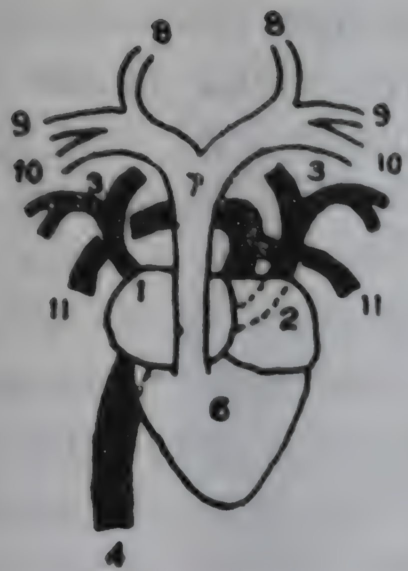


Fig. 1.5 A
Heart of the Frog.
(Ventral view)

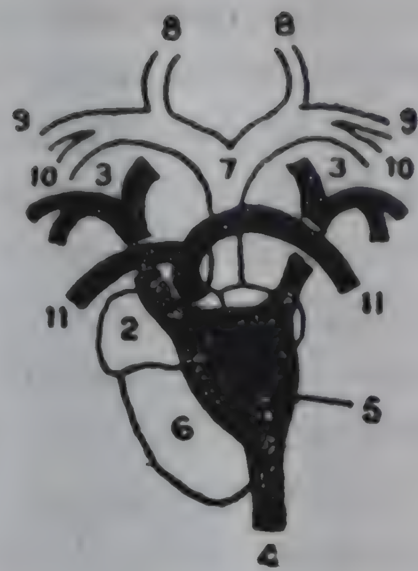


Fig. 1.5 B
Heart of the Frog.
(Dorsal view)

1. Right auricle,
2. Left auricle,
3. Anterior vena cava,
4. Posterior vena cava,
5. Sinus venosus
6. Ventricle,
7. Truncus arteriosus,
8. Carotid,
9. Systemic,
10. Pulmocutaneous,
11. Pulmonary vein.

colour than the auricles and is separated from them by a deep groove. The ventricle is a thick-walled muscular chamber. A thin walled sac called *sinus venosus* formed by a convergence of the *right* and *left anterior* and *posterior vena cavae* is attached to the back of the right auricle and opens into it.

Valves are found between the auricles and the ventricles and also in the incoming and outgoing vessels. They prevent the backward flow of blood from a chamber or a vessel in which it finds itself.

Deoxygenated blood is brought to the sinus venosus from the anterior portion of the body by the right and the

left anterior vena cavae and also from the posterior portion by the posterior vena cava. The blood passes from the sinus venosus to the right auricle. At the same time oxygenated blood is brought to the left auricle from the lungs by the *pulmonary veins*. The sinus venosus and the auricles contract and force a mixture of oxygenated and deoxygenated blood into the ventricle. Thereafter the ventricle contracts and the blood is sent into an artery called the *truncus arteriosus*. This vessel divides into right and left branches each of which divides again into three branches the *pulmocutaneous*, the *systemic* and the *carotid*. The pulmocutaneous carries blood to the lungs and skin, the systemic supplies blood to the trunk and posterior portion of the body and the carotid supplies blood to the head. The first portion of the blood that is discharged into the truncus arteriosus from the ventricle is mainly deoxygenated blood and this blood is carried away for oxygenation to the lungs and skin. Mixed blood follows and is passed along to the trunk and posterior portion of the body. Last comes oxygenated blood which is passed along to the head, through carotid.

Transport System in Man

An average person has about 6.5 liters of blood in his body. The circulatory system in man consists of a heart that works as a pump, arteries that carry blood to different tissues and veins that collect blood from the tissues and bring the blood back to the heart.

Look at the figure 1.6 A and B of the human heart and compare it with that of the frog. Notice the similarities and differences. You can also see how man's heart is an

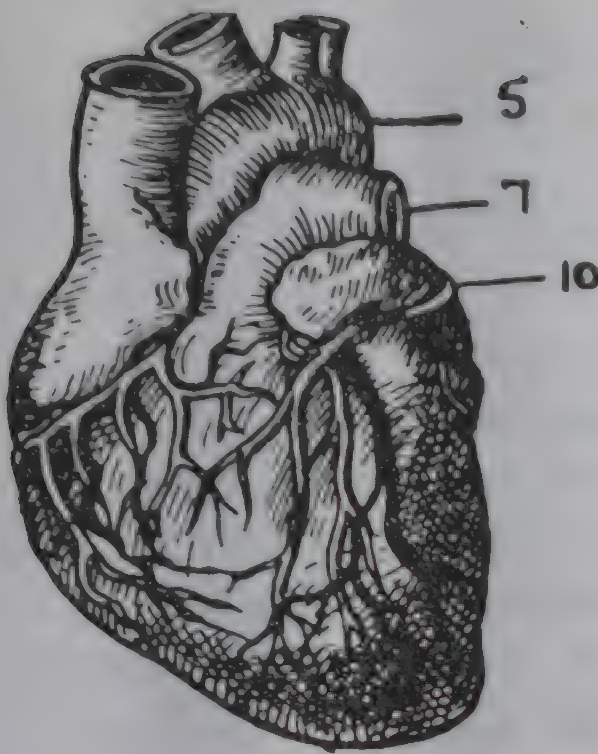
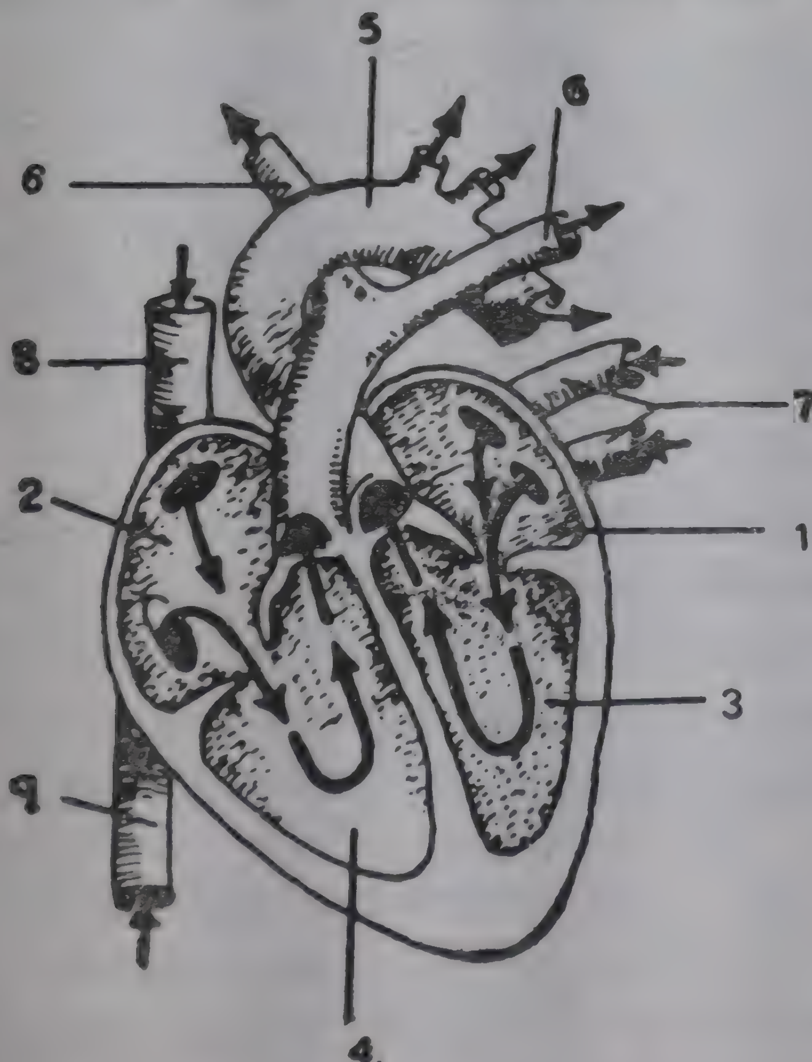


Fig. 1.6A, The Human Heart as seen from the ventral side



1. Left auricle,
2. Right auricle
3. Left ventricle,
4. Right ventricle
5. Aorta
6. Pulmonary artery,
7. Pulmonary vein,
8. Superior vena cava
9. Inferior vena cava,
10. Coronary artery.

Fig. 1·6 B
Parts of the Human
Heart and Associated
Blood Vessels

improvement over that of the frog. The heart is a muscular organ situated in the thoracic cavity between the lungs. About two thirds of the heart lies on the left of the middle line of the body. It is conical in shape and is about the size of one's fist. The heart is enclosed by a double-walled membranous bag called the *pericardium*, the inner wall of which is fused with the outer surface of the heart. The *pericardial fluid* contained in the space of the pericardium lubricates the surface of the heart and reduces friction when the heart expands and contracts. The walls of the heart are thick and powerful and are made up of *cardiac muscles*. A wall divides the heart into two parts, the left and the right. Each part is again divided into an upper auricle and a lower ventricle. The ventricles are bigger and more muscular than the auricles. Between the right auricle and the right ventricle is the *tricuspid* valve which has three flaps. The *bicuspid valve* is between the left auricle and left ventricle and has two flaps. Though the heart contains blood, the walls cannot make use of it. They are supplied with blood through the *coronary arteries* which start from the aorta.

Five main blood vessels are connected to the hear namely the *superior vena cava*, the *inferior vena cava*, the *pulmonary artery*, the *pulmonary vein* and the *aorta*. The superior and inferior vena cava collect the impure blooc from the upper and lower parts of the body and bring it t the right auricle. The *pulmonary artery*, which start from the right ventricle, branches into two and they carr blood to the lungs, while the *pulmonary veins* bring the pur blood back from lungs to the left auricle. Aorta is the larges

artery which takes its origin from the left ventricle and carries blood to different parts of the body. Thus the auricles are the *receiving chambers* while the ventricles are the *distributing chambers* of blood.

Apart from the tricuspid and bicuspid valves, there are two other valves called *semi-lunar valves* situated at the base of the two arteries that leave the ventricles. The valves in general, control the direction in which the blood flows through the heart. All the chambers of the heart and all the blood vessels are internally lined by a layer of smooth, thin, and flattened cells called *endothelium*, which prevents the clotting of blood within the circulatory system.

Circulation of Blood

The circulation of blood in the body was discovered by William Harvey, an English physician about 350 years ago. He studied the hearts of several animals and came to the conclusion that the heart acts like a pump and pumps blood to different parts of the body through arteries, while the veins bring blood back to the heart. However, he did not know how blood goes from arteries to veins. Later, Marcello Malpighi, an Italian scientist continued the work of Harvey with the help of microscope. He found that blood flows through small arteries to the capillaries and then to veins.

There are two distinct circuits in the circulatory system (1) the *pulmonary circulation* and (2) *systemic circulation*.

The Pulmonary Circulation

The pulmonary circulation involves the right ventricle, pulmonary artery, capillary network in the lungs, pulmonary veins and the left auricle (Fig. 1.7).

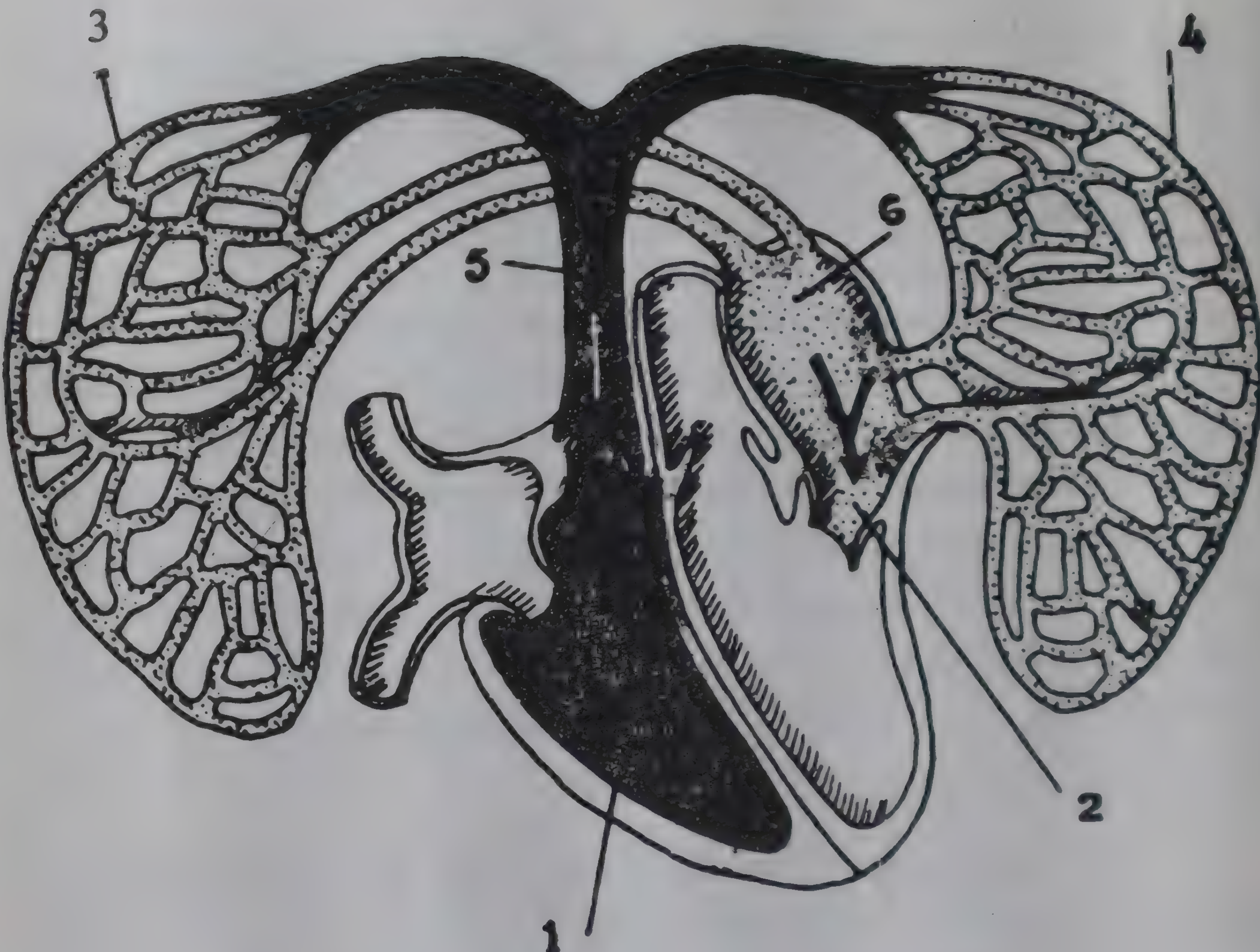


Fig. 1.7. The Pulmonary Circulation

1. Right ventricle,
2. Left auricle,
3. Right lung,
4. Left lung,
5. Pulmonary artery.

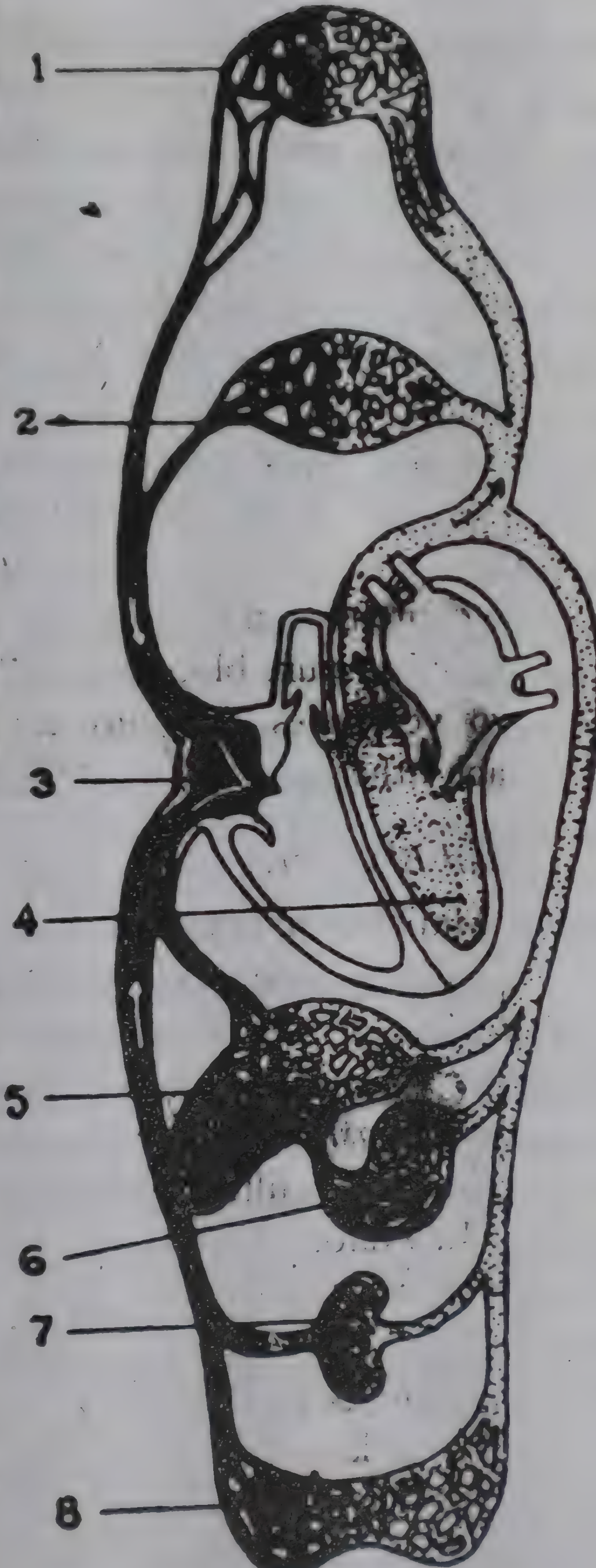
We shall start with blood in the right auricle. When the right auricle contracts, the impure blood containing carbon dioxide passes into the right ventricle through the tricuspid valve. When the right ventricle contracts, blood is pumped into the lungs through the pulmonary arteries. Blood enters the air sacs in the lungs where the exchange of gases take place. The purified blood is collected by the pulmonary veins and poured into the left auricle. *The flow of impure (deoxygenated) blood from the right ventricle to*

the lungs and from the lungs after oxygenation, to the left auricle is pulmonary circulation.

The Systemic Circulation

The systemic circulation involves the left ventricle, the aorta and its branches, the capillary network in different parts of the body other than lungs, inferior and superior vena cavae and the right auricle (Fig. 1.8).

The systemic circulation begins at the left ventricle from where



1. Head,
2. Chest and Arms,
3. Right auricle,
4. Left ventricle,
5. Liver,
6. Stomach and Intestine,
7. Kidneys,
8 Legs.

Fig. 1.8 The Systemic Circulation

oxygenated blood is pumped through the aorta. The aorta gives rise to three branches which supply blood to the head, arms, and shoulders. It forms an arch above the heart and bends downwards to reach the trunk. It branches off and supplies blood to various organs of the abdomen. Going further down it branches into two and each branch goes to each leg. The arteries further branch into capillaries and supply oxygen and nourishment to al parts of the body. Impure blood in the smaller veins return to the heart through inferior and superior vena cavae.

Pulmonary and systemic circulations form th complete circulation in the body. In frog there is a mixtur of pure and impure blood in the ventricle. In man ther are two ventricles. So, pure and impure blood do not mi with each other.

Pulse and Blood pressure

Many a time you must have seen a doctor using stethoscope to 'feel' the *heart-beats* of a patient. Th enables him to assess the working of the heart. Eac heart-beat results from a contraction (*systole*) and a expansion (*diastole*) of the heart. During diastole the tw auricles become filled with blood poured into them b veins. In systole the blood is pumped out of the hea into the arteries. The two processes take a total of abo 0.8 seconds so that you can feel nearly 70–75 beats p minute. The beating of the heart is also felt in the arteri as regular jerks or *pulses*. When the ventricle sudden pushes the blood into the arteries through the aorta, t latter undergoes extra distension owing to the additio

amount of blood. This distension causes pulsation in the arteries. You can feel your pulse wherever the arteries lie under the surface as on the wrist, neck and temples.

The flow of blood in the arteries exerts a pressure on their elastic walls. This pressure is greater during systolic action than a diastolic action. The two pressures are usually measured in terms of pressure exerted on a column of mercury. This can be measured by an instrument known as *sphygmomanometer*. In a normal adult the blood pressure or the systolic and diastolic pressures are 120 and 80 mm. of mercury respectively. It is expressed as 120/80 mm. Hg. Blood pressure is influenced by a number of factors such as the type of food, age, sex, heredity, physical exercise and emotions.

Blood Filters-Spleen and Liver

Spleen is a small organ situated on the left side of the abdomen just below the diaphragm. It has a rich blood supply. It serves two main functions. It filters the dead red blood cells from the blood flowing through it and acts as a reservoir holding a lot of blood. Whenever there is a haemorrhage (loss of blood) spleen releases the reserve blood into circulation. In the human embryo it is also the site of formation of both red and white blood cells.

The liver is one of the largest and important organs of the human body. It acts as a gland, a storage organ and an excretory organ. In fact one might say that liver is the greatest chemical factory in our body. All the food materials absorbed from the intestines into the associated blood vessels (excluding fats which are absorbed directly into the lymphatic system) are first brought into the liver

by the *hepatic portal vein*. There it is distributed to live cells by means of a capillary network. Most of th glucose is removed and stored as insoluble glycoger Glycogen may be reconverted into glucose and release into the blood when needed. Amino acids are partly cor verted to proteins and partly broken down.

In addition to the above, liver produces bile which ha an important role in the digestion of fats. As blood flov through the liver, worn out red blood cells are destroye and the haemoglobin molecule is broken down. A part haemoglobin called *haem*, is converted to bile pigmen while the iron in it is stored in the liver. Jaundice is cause by disturbances in the activity of the liver. The bi pigments increase in the blood stream. In severe cases th skin may appear yellowish. This may be due to eith some obstruction in the flow of bile into the duodenum due to an excessive breakdown of red blood cells. A defe in any of the important functions of the liver cou seriously affect health.

Care of the circulatory system

For the proper functioning of the different parts of t body, it is essential that they are adequately provided wi food and oxygen. This is possible only when we keep t circulatory system healthy. Adequate quantities of protei iron and vitamins are essential for the production of bloo

Artery damage may be caused by too much of fat the diet. Heart attacks may result when the arter supplying blood to the heart are damaged. Being ov weight is also hard on the heart. We should stay at norn weight all through life. Therefore special attention m

e paid to the heart since it works throughout life. Modern life, full of tensions and worries, often results in high blood pressure or hypertension. This means the heart is forced to do more work than it is capable of and may give way any time. It is important, therefore, that we should keep our emotions under control.

Activities

1. Examine the different kinds of blood cells under a microscope.
2. Observe clotting of blood on a wound.
3. Examine the different parts of the heart of a goat or a sheep.

   Note : The structure of the heart and the blood constituents in goat and sheep are similar to those in human being.
4. Place your ear on the chest of another person and listen to the heart-beat.
5. Observe how a doctor finds out the blood pressure of a patient.

Questions

1. What is transport system ? Mention its functions.
2. What are the differences between RBC and WBC ?
3. What is clotting of blood ? Mention its advantages.
4. Distinguish between open and closed type of transport system and give examples ?
5. What is haemocoel ? Where do you find this ?
6. Draw a neat diagram of the heart of the cockroach and label the parts.
7. Name the main blood vessels in earthworm.
8. How is man's heart an improvement over that of the frog ?
9. What is pulmonary circulation ? How is blood purified in the lungs ?

10. What is heart beat ? How do you find it ?
11. What is blood pressure ? Name the instrument used to measure the same.
12. What are the functions of liver and spleen ?

II. *Fill in the blanks* :

1. plasma ——— is the liquid part of the blood.
2. The protein which produces immunity is ———
3. Uncontrolled production of WBC causes ——— disease.
4. Sinus venosus ——— is formed by the convergence of anterior vena cava and posterior vena cava.
5. ventricles ——— are the distributing chambers of the heart.

III. *Name the following* :

1. The protein which helps in clotting of blood.
2. The pigment which gives colour to the blood.
3. The blood vessel of the frog which carries blood to the lungs and skin. pulmocutaneous
4. The valve which is present between right auricle and right ventricle. Tricuspid
5. The membrane which encloses the heart.
6. The vein which brings pure blood.

IV. *Give reasons* :

1. Red blood cell can pass through blood vessels smaller than its diameter.
2. Dorsal blood vessel of the earthworm is called collecting vessel.
3. Blood circulation in frog is incomplete.
4. Blood does not carry out the respiratory function in cockroach.
5. Right auricle contains deoxygenated blood.

Deoxygenated blood collected from the various parts of the body through veins first flows into the auricle

* * *

CHAPTER 2

Excretory System In Animals

Many by-products are formed as a result of metabolism of materials in the cells. Some of these by-products may become toxic if they accumulate beyond a certain concentration. So their removal becomes necessary. This is done by the body by the process of *excretion*. *Excretion may be defined as the process of elimination of metabolic waste products from the living tissues of an organism.*

The principal by-products of metabolism include carbon dioxide, water and nitrogen-containing compounds like ammonia, uric acid and urea.

1. Carbohydrates + oxygen ⟶ Carbon dioxide + water
2. Fats + oxygen ⟶ Carbon dioxide + water
3. Protein and amino acids + oxygen ⟶ Carbon dioxide + water + ammonia

Ammonia converted to urea.

Ammonia converted to uric acid.

Fig. 2.1 : Scheme of by-products formed when sugar, fats and proteins are oxidised.

We have already studied the production and elimination of carbon dioxide during respiration by respiratory organs like lungs, skin and gills. We shall now consider the origin and disposal of ammonia as well as nitrogenous wastes.

Ammonia

Ammonia is formed during protein metabolism. It is highly soluble in water and is toxic. Generally excretion of ammonia requires large amounts of water in the surrounding media. Small aquatic animals like protozoans excrete nitrogen in the form of ammonia which readily diffuses across the body surface into water. Many invertebrates also excrete in the form of ammonia. Some aquatic reptiles like crocodiles excrete ammonia.

Urea

Urea is another nitrogenous waste product. It is a compound highly soluble in water but it is much less toxi than ammonia. So many vertebrates convert ammoni (formed during protein and amino acid metabolism) to ure in their liver. The urea so formed is much less toxic. I is released into the blood where it can be present at a muc higher concentration than ammonia. It is eliminated fro the blood by the kidney as *urine*. Like ammoni excretion of urea also requires a large amou of water because, it can be removed only in the dissolv form. Mammals, amphibians and fishes and many inverte brates excrete nitrogenous waste in the form of urea.

Uric acid

Unlike ammonia and urea, uric acid is quite insolub in water. It therefore crystallizes when water is reduce It is non toxic in this form and can be excreted in the for of a solid or semisolid paste.

Like urea, uric acid is formed from ammonia in t animal body. In vertebrates it is formed in the liver. the toxic action of ammonia is avoided by converting it

uric acid. During its excretion only a small amount of water is lost and the animal conserves water. Birds, reptiles and many insects excrete nitrogenous waste mainly as uric acid. The white dropping of birds is mainly a paste of uric acid.

The process of getting rid of faeces is not excretion. It is not a metabolic product. It consists of undigested materials which have never really entered the body tissues.

Excretion In Amoeba

No special excretory structures are present in amoeba. Excretory materials such as carbon dioxide and ammonia are present in higher concentration in the protoplasm since they are being produced continuously. They diffuse across the plasma membrane into the surrounding media.

Excretion In Hydra

In hydra, the chief excretory product is ammonia; in addition to it very small quantities of urea and uric acid are also produced. There are no definite excretory organs in hydra. Almost all parts of the body are in contact with the external medium namely water. Outer ectoderm is in contact with outside water and inner endoderm is in contact with water present inside the gastrovascular cavity. Water circulates in the gastrovascular cavity by the movement of cilia of endodermal cells. Nitrogenous waste products are continuously produced in the cells, and they diffuse into the surrounding water.

Excretion in Earthworm

Earthworm excretes mainly urea and ammonia. The primary excretory system in earthworm consists of coiled

tubes called *nephridia* which are found in pairs in all segments except a few at the anterior and posterior ends. The position of these structures in the body is shown in Fig. 2.2. Each nephridium occupies a part of the two successive

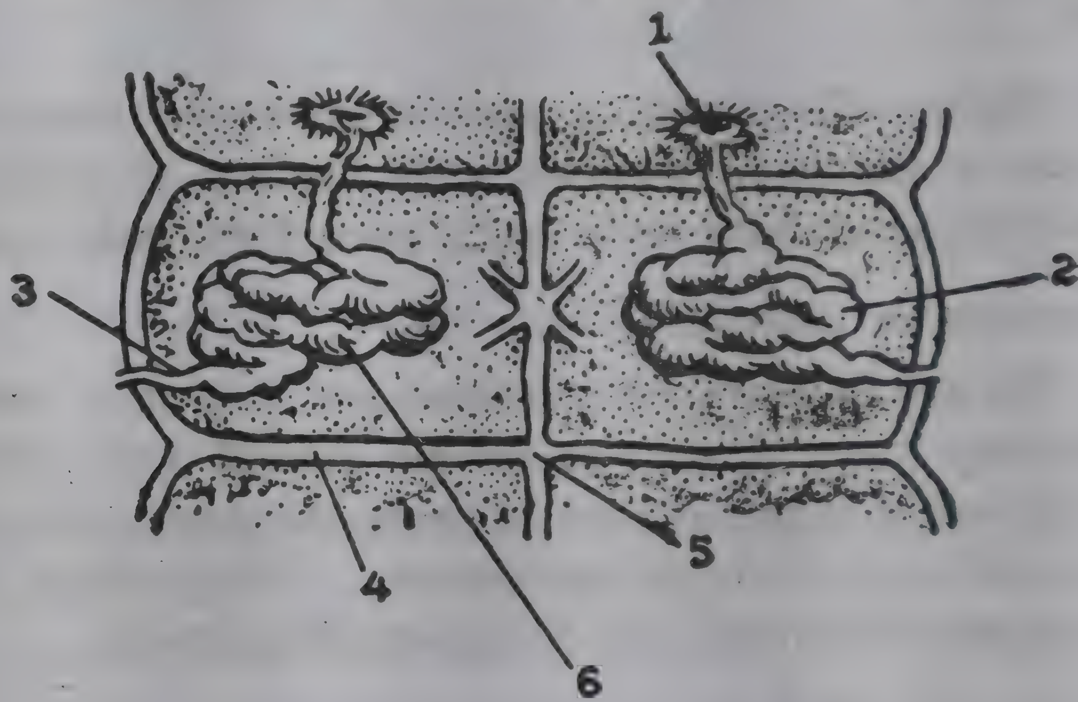


Fig. 2.2. Nephridia in Earthworm

1. Nephrostome
2.6. Nephridium
3. Nephridiopore
4. Septum
5. Ventral nerve cord

segments. It consists of a ciliated funnel-shaped opening (*nephrostome*) and a highly coiled tube which empties to the external surface of the succeeding segments of the body through *nephridiopore*. The cilia of the nephrostome draw fluid containing wastes into the nephridium from the body cavity. During its passage through the nephridium the useful substances are absorbed by the capillaries around it and the wastes are thrown out through the nephridiopore.

Excretion in Cockroach

Cockroach has specialized excretory structures called *Malpighian tubules* found floating in the *haemocoelic* fluid

Fig. 2.3). The outer ends are blind while their inner ends open into the alimentary canal between the midgut and the hindgut. The malpighian tubules collect the nitrogenous wastes from the blood and pass them into the alimentary canal. The waste products leave the body with the undigested food materials. The chief nitrogenous waste produced is uric acid. Carbon dioxide is disposed off to the exterior by way of the tracheal tubes.

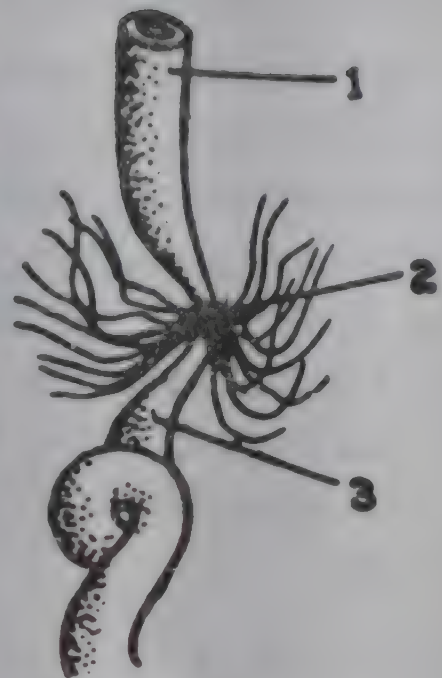


Fig. 2.3. Excretory Organ in Cockroach
1. Midgut
2. Malpighian Tubules
3. Hindgut

Excretion in Fish

The excretion in fish is brought about by the kidneys and the gills. The kidneys are generally long, thin, dark red glands extending along the entire length of the trunk below the vertebral column. The nitrogenous waste products are removed in the form of urine.

Aquatic organisms are faced with special problems in regulating water content in their cells and tissues. The tissue fluids of the fresh water fish have more salt and less water than the surrounding environment. Thus salt and other solutes tend to pass out of the organism and water tends to pass into the body. This excess of water is eliminated in the form of dilute urine by the kidneys, while the salts are absorbed from outside water by specialized cells

located in the gills. The outer covering of the fish is tough and scaly, and relatively impermeable to water.

The salt water fish have the reverse problem. Their tissue fluids have less salt and more water than the surrounding environment. Thus salt would tend to pass in and water to pass out of the organism. These fish swallow sea water, discard the salt and conserve the water. The discarding of salt is done by specialized cells in the gills. The gills also excrete wastes in the form of ammonia. These fish also conserve water by excreting only small quantities of urine.

Excretion in Frog

In frog the excretory system and reproductory system are closely associated. Hence they are often considered together as the *urogenital* system.

A pair of kidneys, a pair of *ureters* and a *urinary bladder* constitute the main parts of the excretory system. The kidneys are flattened, elongated, reddish-brown structures located in the abdominal cavity on either side of the vertebral column. (Fig. 2.4). Both the ureters open into the urinary bladder. The kidney consists of a mass of twisted microscopic tubules, the *urinary tubules*. The urinary tubules are the *functional units of the kidney*. The soluble excretory substances like urea and salts of potassium, sodium, calcium and magnesium along with uric acid are brought to the kidneys by the renal arteries. Filtration of blood takes place in the capsule at one end of the tubule. All the substances present in the blood, except proteins and red blood cells, are filtered down. Useful materials like sugars, sodium salts and water are reabsorbed by the

capillary network. The rest of the excretory products flow down the tubule as urine. The wastes are eventually emptied into the *ureter*. In the male frog, these ducts also carry

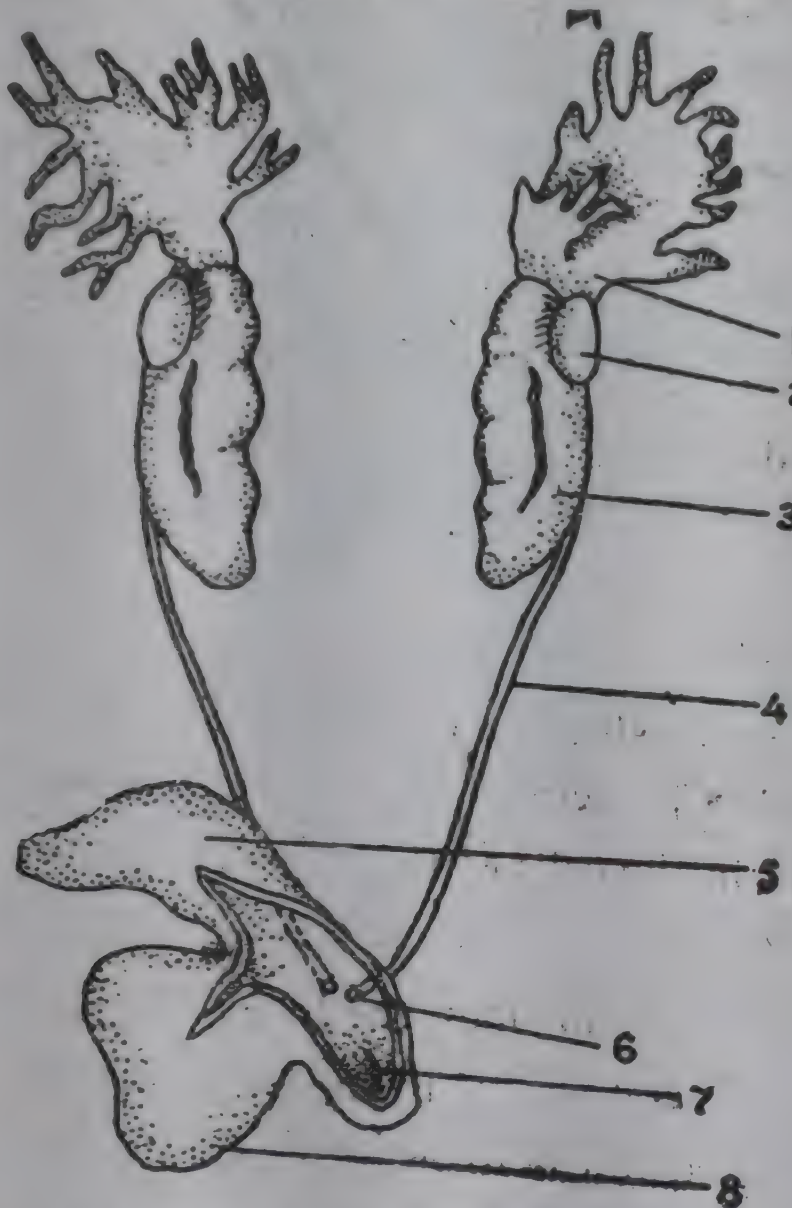


Fig. 2.4. Male Urogenital System in Frog

1. Fat body
2. Testis
3. Kidney
4. Ureter
5. Rectum
6. Opening of ureter
7. Cloaca
8. Urinary bladder

perm or male gametes. Hence they are called *urogenital ucts*. These ducts lead to the *urinary bladder* which mpties at intervals into the cloaca and then to the exterior. idneys also regulate the quantity of water in the body f frog.

Excretion in Man

You know that many kinds of chemical changes take place in our body. Energy is released during respiration and is used for many activities of life. The waste products formed are carbon dioxide, water and nitrogen containing compounds such as urea and some uric acid. Carbon dioxide is removed from the body by the lungs in the process of respiration. The other waste products are eliminated from the body by the excretory organs, namely the skin and the kidneys.

The amino acids are transported by blood from the digestive system to liver. Part of amino acids are converted into proteins. Part of these amino acids are broken down in the cells of the liver. During the breakdown of the amino acids, ammonia is formed which is toxic. With the help of certain enzymes the liver cells convert ammonia into urea which are carried to the kidneys by the blood and finally eliminated in the form of urine.

Excretory system in man consists of two *kidneys* two *ureters*, *urinary bladder* and *urethra* (Fig. 2.5). The kidneys produce urine, the ureters carry the urine gathered in the kidneys to the urinary bladder, which is a muscular sac-like reservoir for the temporary retention of urine. The urethra is a duct which drains the urine to the outside—a process known as urination.

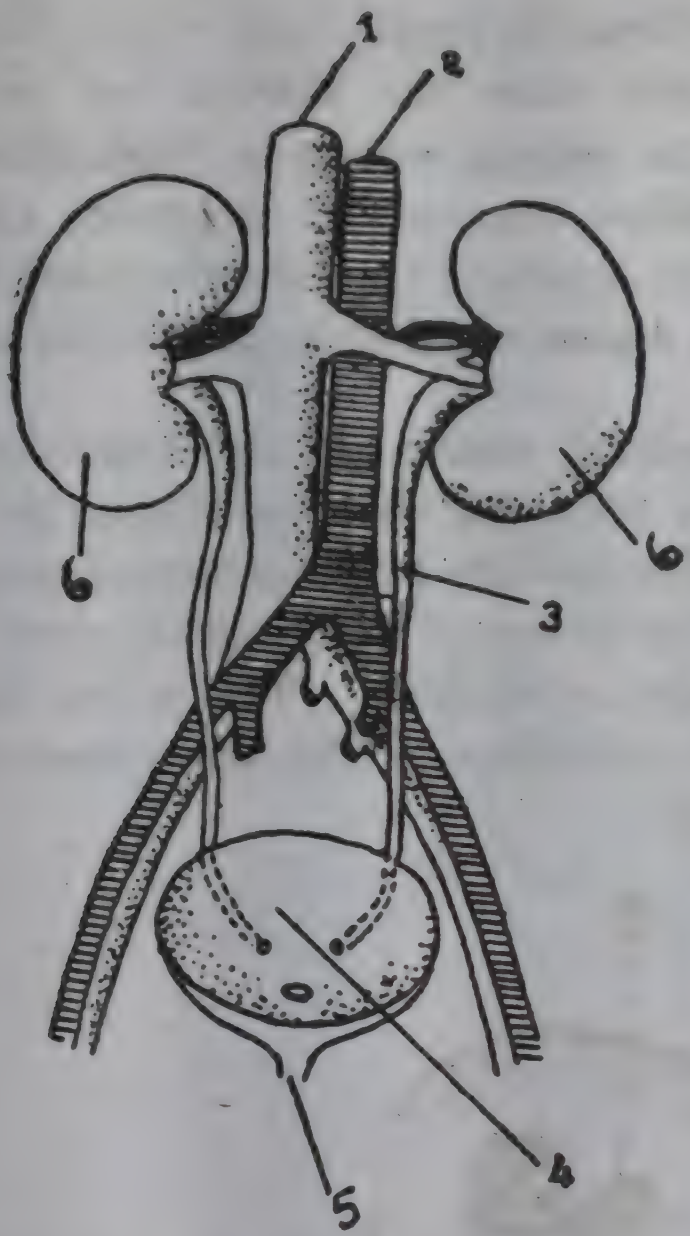


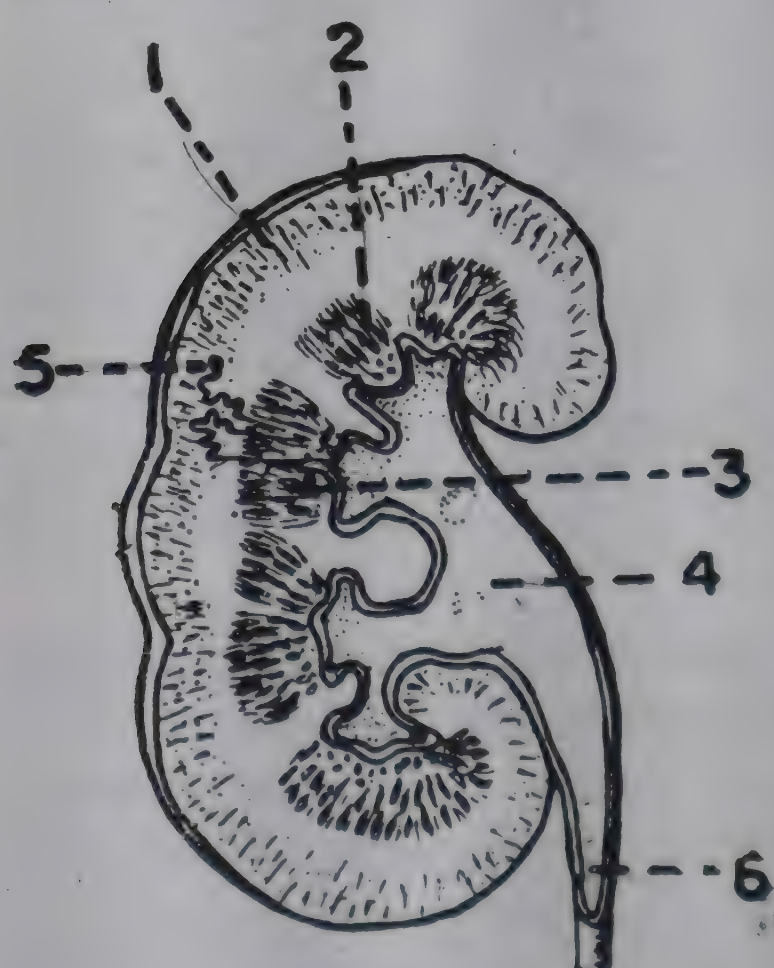
Fig. 2.5. The Excretory system in Man.

1.	Inferior vena cava	4.	Urinary Bladder
2.	Aorta	5.	Urethra
3.	Ureter	6.	Kidneys

The kidneys are a pair of reddish-brown, bean-shaped organs, situated at the back of the abdominal cavity, one on either side of the vertebral column. In man each kidney is about 5–6 inches long and two inches wide. Thick layers of fat are found around the kidneys. These serve as protective covering. The concave side is towards vertebral column and convex side faces outwards. Kidneys receive

blood supply from the renal artery arising from the aorta Blood, collected from the kidneys by the renal veins empties into the inferior vena cava. Each kidney consists o about one million microscopic structures called *nephrons* Nephron is the structural and functional unit of the kidney Nephrons are bound together by connective tissues.

A longitudinal section of the kidney shows that it i formed of two zones–the outer *cortex* and the inner *medull* (Fig. 2.6). The medulla contains conical projections calle *pyramids*. The points of the pyramids open into a sac-lik cavity, the *pelvis of the body*. The pelvis leads to a lon narrow tube called ureter. The two ureters empty into th urinary bladder.



1. Cortex
2. Medulla
3. Renal Papillae (in pyramids)
4 Renal Pelvis
5. Position of a nephron
6. Ureter

Fig. 2.6 Longitudinal section of the Kidney

Each nephron begins in the cortex as a double-walled cup called the *Bowman's capsule* (Fig. 2.7). The cavity of

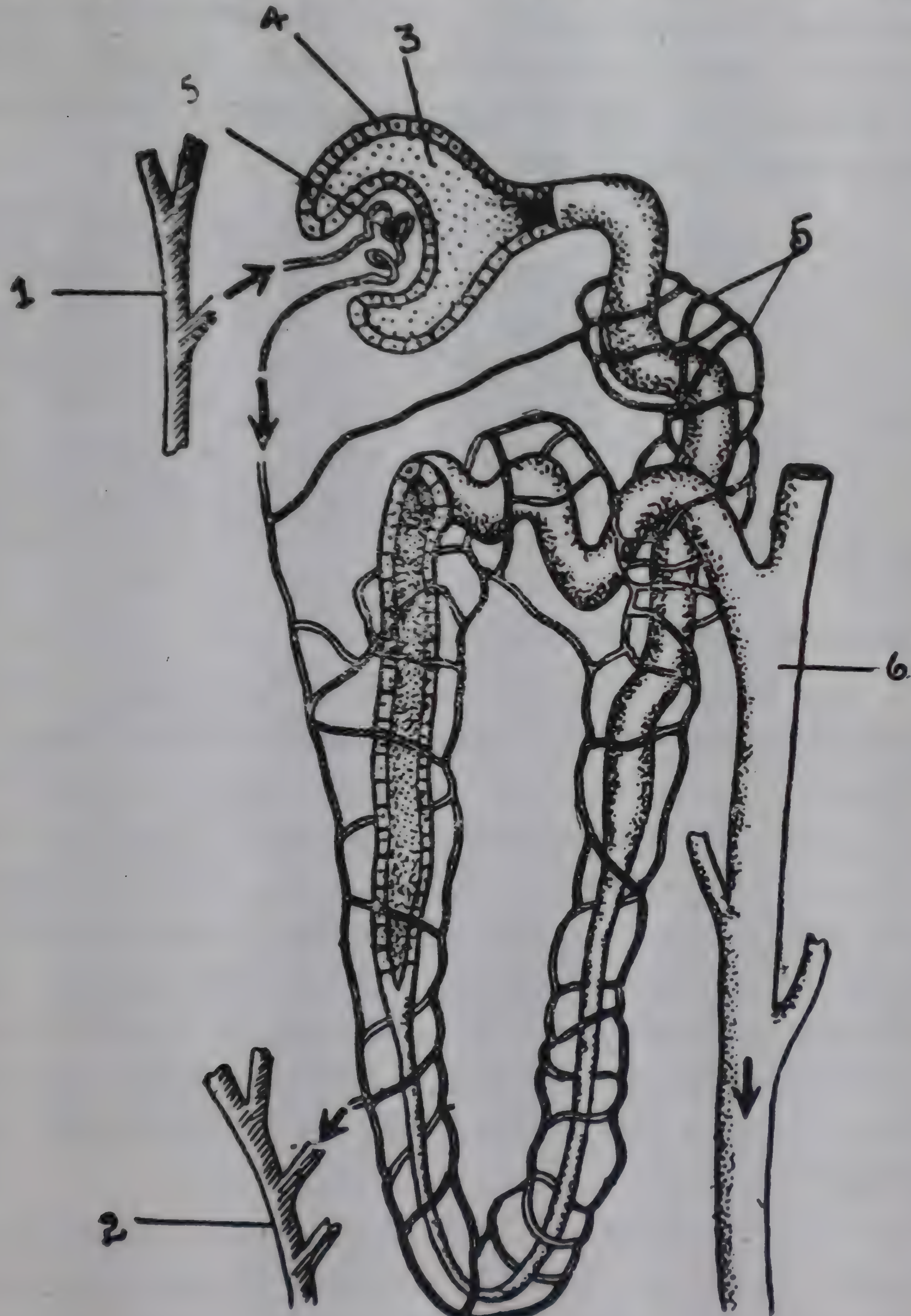


Fig. 2.7. Uriniferous Tubule and Blood Vessels
1. Branches of an artery 2. Branch of a vein 3. Bowman's capsule
4. Epithelial cells 5. Capillaries 6. Collecting tubule

the cup surrounds a network of capillaries called the *glomerulus*. There is a long tubule extending from each Bowman's capsule, called *uriniferous tubule*, the coiled portion of which lie in the cortex and the straight portion in the medulla. All along its length each tubule is lined with a single layer of cells

The blood vessels that leave the glomerulus form another network of capillaries around the coiled portion of the tubules, and finally emerges as a small vein. The fact that the renal artery must pass through two sets of capillaries before reaching a renal vein is an adaptation for the functioning of the kidneys. A number of nephrons join together and open at the renal papillae (in pyramids) into the pelvis.

Formation and disposal of urine

The amount of urine formed by an average adult is about 1.5 litres per day. The volume of urine formed is influenced by factors such as water intake, water loss, diet, metabolic rate and muscular activity. Urine is usually clear. It's straw or yellow colour is due to the presence of several pigments that are collectively called *urochrome*. Urine is a mixture of several organic and inorganic constituents. About 96 per cent of urine is water and the remaining 4 per cent consists of dissolved solids, including inorganic salts and nitrogen-containing compounds such as urea.

Three distinct steps are involved in the formation of urine. These are *glomerular filtration*, *tubular reabsorption* and *tubular excretion*. Blood brought into the kidney by the renal artery finds its way through small arteries into the

glomeruli. Increased blood pressure within the glomerulus force a large percentage of the fluid portion of the whole blood into the Bowman's capsule. All the dissolved constituents of plasma except proteins and blood cells filter through this membrane. As the glomerular filtrate flows down the tubule, the single layer of epithelial cells which forms its lining absorbs useful materials such as glucose, amino acids and salts and reintroduces these into the blood in the capillary network around the tubule. This process is known as *active transport*. An active transport involving the reintroduction of these useful materials (glucose, amino acids and salts) into blood is collectively termed as tubular reabsorption. When these substances are moved by active transport into the blood in the capillaries, it's osmotic concentration rises. Water moves out of the tubules and diffuses into the blood. By this process much of the water removed by glomerular filtration is reabsorbed by the blood.

The third and the final step in the formation of urine is tubular excretion during which the epithelial cells of the tubule actively remove additional waste substances such as urea, uric acid from the blood that have escaped filtration and introduce them into the filtrate. Thus as a result of tubular reabsorption and excretion, the glomerular filtrate passing down the tubule is gradually converted into urine, small amounts of which trickle into the renal pelvis through the perforation on the renal papillae. *Peristalsis* of the ureter moves the urine from the renal pelvis to the urinary bladder where it is stored temporarily. Urinary bladder is a muscular sac which holds the urine until it can be passed off to the outside of the body.

Care of the Excretory System

Normally urine does not contain glucose, but sometimes it may have 0.1 per cent or even more. A high level of sugar may be due to a disease called *diabetes* which interferes with the conversion of unused sugar into glycogen. Urine sometimes contains blood. This may be due to some damage to the filters of the kidney. By analysing the urine of the patient, the doctor can often diagnose the disease.

SKIN

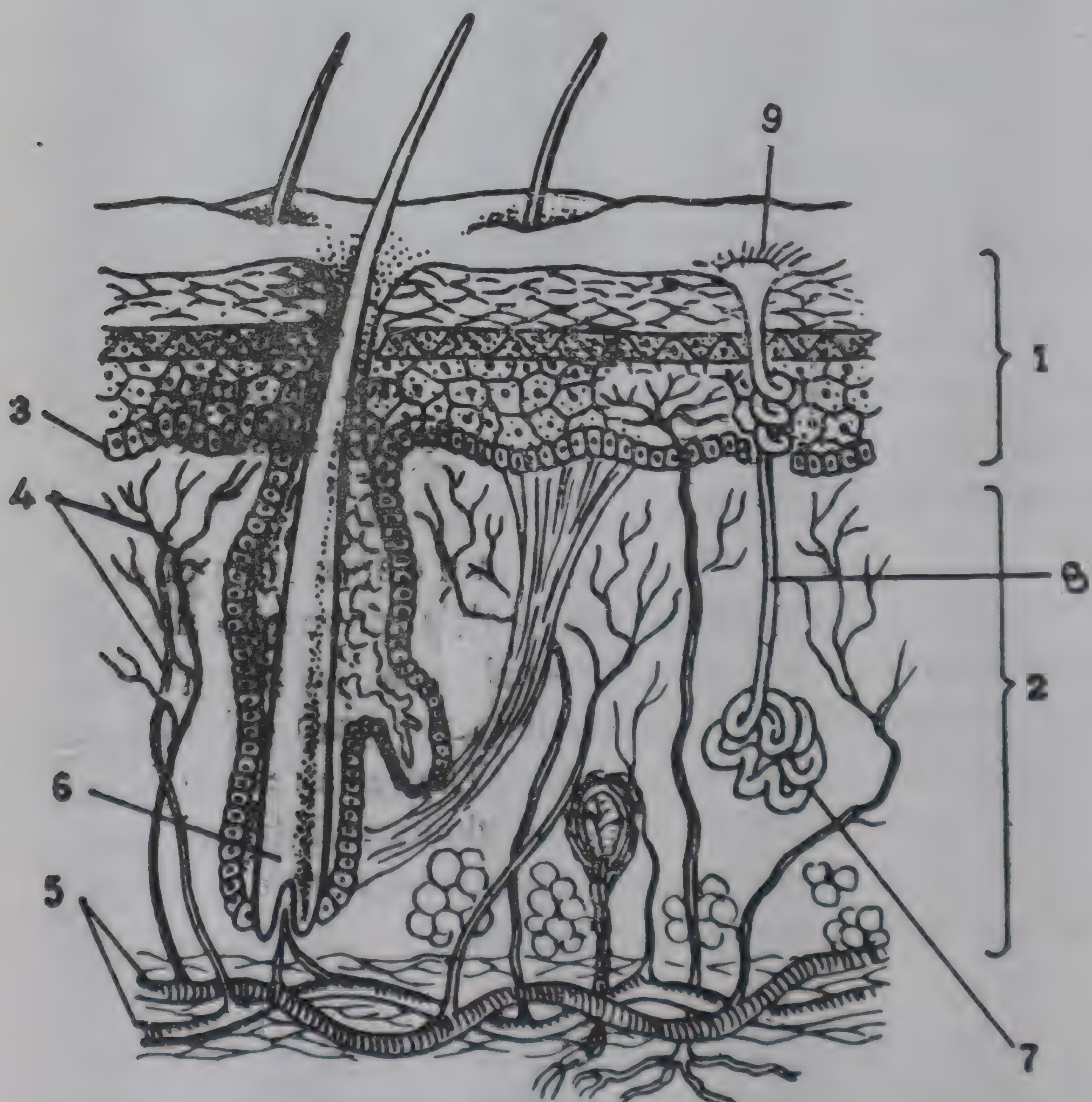


Fig. 2.8. Structure of the skin

1. Epidermis
2. Dermis
3. Germinating layer
4. Nerves
5. Blood vessels
6. Hair follicle
7. Sweat gland
8. Sweat duct
9. Sweat pore

The main function of the skin is protection. In addition to this, skin is also involved in excretion, and the regulation of body temperature. Skin has two layers namely, the *epidermis* and the *dermis* (Fig. 2.8).

The epidermis forms the outer part of the skin and has several layers of dead epithelial cells. Only the lowermost layers of the epidermis consists of living cells which are constantly producing new cells to replace the cells worn off from the upper layers. Colour of the skin is due to the pigment *melanin* present in this layer.

The dermis consists of living cells. It is made up of connective tissue and has a number of *sweat glands*, hair follicles associated with oil glands, nerve endings and blood vessels. The sweat gland is in the form of a coiled tube and discharges sweat by means of a duct opening to the outside. It eliminates water, salts and some urea from blood in the form of sweat. These glands are directly stimulated by the nerve endings located in them and indirectly through the sensory nerves of the skin. The glands are also influenced by external factors like heat and humidity. On hot summer days you sweat more. Some heat from the body is removed when the water in sweat evaporates. So the body becomes cooler. Thus the body regulates its temperature.

During winter the activity of the sweat glands is reduced. The body does not have to remove excess heat. Excess water is removed by the kidneys and the quantity of urine excreted is increased.

Questions

1. What is excretion ?
2. Name the excretory organ of an earthworm. Describe the process of excretion with the help of a neat diagram.
3. How do fresh water fishes regulate the water content in their body ?
4. What is meant by uro-genital system ? Wh do you find this ?
5. Draw a neat diagram of the longitudinal ion of a kidney of man and label the parts.
6. Which are the three steps involved in the for tion of urine in man.
7. What is active transport ? Where does it take place ?
8. Draw a neat diagram of the skin of man and label the parts.
9. How does the skin regulate body temperature ?

II. Fill in the blanks :

1. Ammonia is formed during —— metabolism.
2. Urea is eliminated from the blood by the kidney as ——
3. Uric acid is insoluble in water.
4. In cockroach, carbondioxide is disposed off through ——
5. Salt water fishes discard salts by specialised cells in gills
6. —— is the structural and functional unit of the kidney.
7. Dermis layer of the skin contains living cells.
8. Melanin pigment gives colour to the skin.

III. Name the following :

1. Ciliated funnel shaped opening of the nephridium
2. The excretory organ of the cockroach.
3. The microscopic tubules present in the kidney.
4. The cup like structure of the nephron.
5. The pigment which gives straw colour to the urine

IV. Give reasons :

1. Many vertebrates convert ammonia to urea in the liver.
2. In male frogs the ureters are also called urogenital ducts.
3. Thick layers of fat are found around the kidneys of man.
4. Skin is a supplementary excretory organ.

* * * *

CHAPTER 3

Control and Coordination—Nervous System

Suppose you were asked how you spent your summer vacation, you would probably reply that you enjoyed yourself very much. Now can you analyse how exactly you did it ? Biologically speaking, this was possible because you possess the *sense organs :* eyes, ears, nose, tongue and skin which enable you to see, hear, smell, taste and feel. Each of these organs receives a particular kind of information from the surroundings, passes it on to the *brain*, the master organ which processes and synthesizes the various kinds of information and gives you the ability to appreciate and enjoy beautiful things.

All your reactions towards the environment are due to the work of your *nervous system*, with brain as the centre, which *coordinates and controls* your actions. It also controls the actions of the muscles as well as the glands and adjusts the individual to the outside environment. If an organism is to adjust to these environmental and metabolic changes, it must have the ability to receive a *stimulus* and to effect an appropriate *response*. An environmental change that causes an organism to respond is known as a stimulus. For instance, if you are crossing a road and see a car coming towards you, you step back and let it pass. The sight of the car is the stimulus, and stepping back is your response. All organisms respond to stimuli.

Nervous system consists of *receptors and conductors* and its action is felt upon *effectors*. The organ which

Nephridium are Excretory organ of Earthworm

receives the stimulus is called the receptor. The organ which shows the response is the effector. The tissues which connect the two (receptors and effectors) and help to conduct the stimulus are called conductors. In higher organisms, the receptors are the sense organs, the effectors are muscles and glands, and the conductors are the nerve cells or *neurons*. The neurons with their processess, the dendrites and axons, form a network of communication between the receptors and effectors. Thus while nerve cell bodies are located in the brain and ganglia, their processes (the fibres) extend to all parts of the body. Ganglia are clusters of nerve cell bodies. The neurons and their supporting cells called *the glial cells*, make up the nervous system.

Functions of the Nervous System

(1) It receives stimuli from the surroundings, and originates responses.

(2) It co-ordinates the activities of the individual cells in multicellular organisms. This leads to a considerable degree of inter-dependence among various parts of the higher organisms.

(3) It is specially adapted for the rapid transmission of impulses. The impulses are sent in two ways, one from the tissues and organs to the nerve centres and the other from the nerve centres to the tissues and organs.

Evolution of the Nervous System

The organization of the nervous system varies among the various forms of life. It becomes progressively complex and better organized as we proceed from the simple to the

higher organisms. Unicellular organisms like *Amoeba* have no neurons. Nevertheless it manages to show simple responses by moving away when touched with a fine needle or by moving towards food.

Nervous System of Invertebrates

Hydra

The nervous system in hydra is simpler than that of the higher animals. This is of a primitive type, since differentiation of nerve tissue has not reached a higher level.

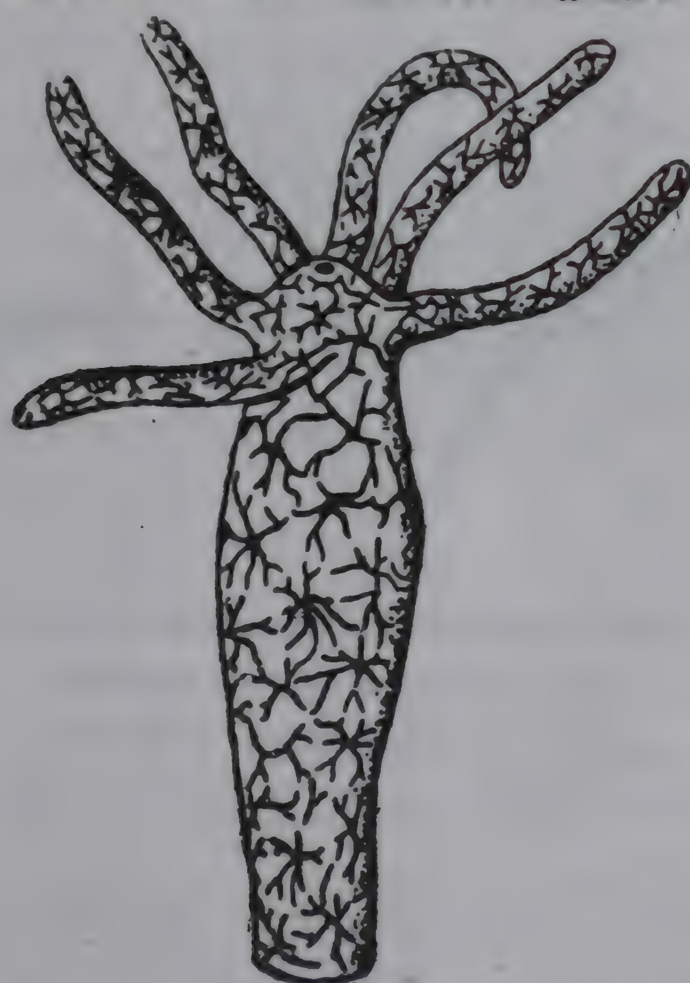


Fig. 3.1. The Nerve Net of Hydra

It consists of neurons, its branched processes are connected to form a nerve net (Fig. 3.1). The nerve net is more concentrated around the mouth.

Hydra has no brain, ganglia or nerves. Some of the branches of the nerve net are connected to receptor cells

and contractile cells. The conduction of impulses is slow and is described as diffuse. The diffuse nature is shown by the fact that the whole animal responds to a stimulus applied to any part of the body.

Earthworm

The nervous system of the earthworm is more complex than that of hydra. It shows the concentration of neurons

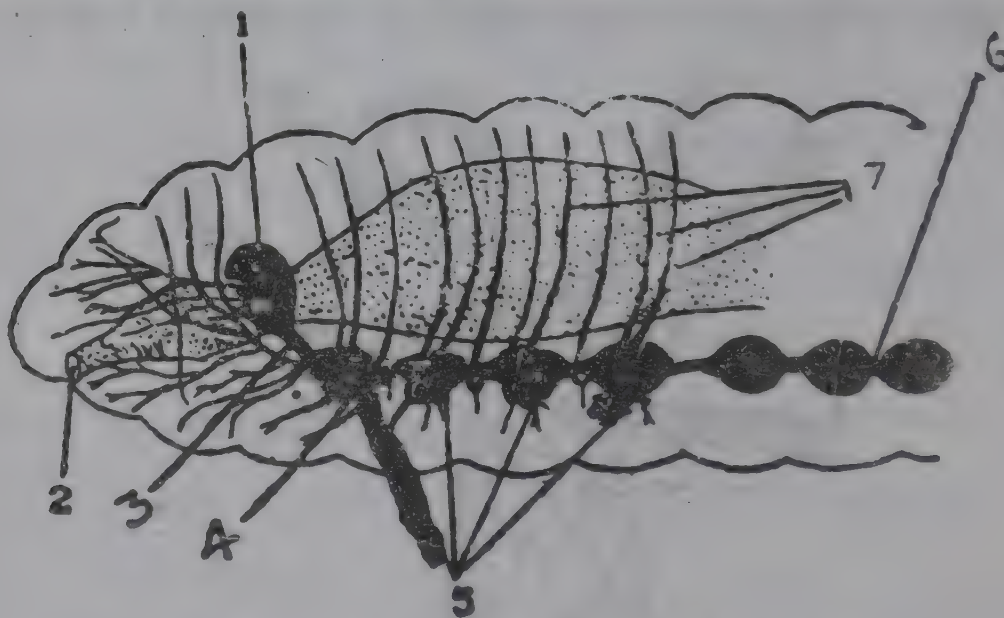


Fig. 3.2. The Nervous System of Earthworm
1. Cerebral or Suprapharyngeal ganglia (Brain)
2. Mouth 3. Circumpharyngeal commissure
4. Subpharyngeal ganglia 5. Segmental ganglia
6. Nerve cord 7. Nerves.

into ganglia and nerves. Thus we are able to differentiate the two typical functional parts of the nervous system (Fig. 3.2).

The cerebral ganglia (brain or *supra pharyngeal ganglia*) are the two spherical masses lying dorsal to the pharynx, in the region separating the buccal cavity from the pharynx. Two collar-like *circumpharyngeal* (' *surrounding the pharynx* ') *commissures* start from the brain, completely encircle the pharynx and meet at the *subpharyngeal ganglia.* The nerve cord starts from these ganglia and runs the whole

length of the body in the coelom. It lies below the ventral blood vessel. In each segment the nerve cord swells into a *segmental ganglion.* Nerves start from the cerebral ganglia, commissures, subpharyngeal ganglia and segmental ganglia. Though the ventral nerve cord appears to be single, it is actually double as can be seen in a transverse section.

Nervous System of Vertebrates

The nervous system of vertebrates like frog and man differ from that of invertebrates. The brain is highly developed and the nervous system in general has the following three important features: (1) The vertebrate nerve cord is hollow and the cavity extends throughout the spinal cord and brain. (2) It lies dorsal to the digestive system. (3) The nerve cord is single.

In vertebrates there are two principal anatomical divisons of the nervous system, namely, (*1*) *the central nervous system* (*CNS*), and (*2*) *the peripheral nervous system* (*PNS*). The CNS consists of the brain located in the skull, and the spinal cord in the trunk region within the vertebral column. The peripheral nervous system consists of cranial nerves arising from the brain and the spinal nerves arising from the spinal cord.

From a functional point of view the voluntary muscles are under the direct control of the CNS but the activity of involuntary muscles such as those in heart, stomach, lungs etc., and of the glands is regulated by a more complex arrangement called the *autonomic nervous system.*

Nervous System of Frog

Frog has 10 pairs of cranial nerves. While some cranial nerves are purely sensory, some are purely motor

and a few others are mixed nerves. The tenth nerve called the *vagus* (wandering nerve) which enters the trunk region, connects chiefly the stomach, the lungs and the heart. Except the vagus, the others are confined to the limits of the head and the neck. There are ten pairs of spinal nerves in frog.

Nervous System in Man

The nervous system in man may be compared to a telephone system with the brain doing the work of a telephone exchange. The groups of nerve cells (ganglia) in the spinal cord act as local exchanges. Nerves may be compared to telephone wires connecting every part of the body either directly or indirectly to the brain. Nerve impulses are like the telephone messages.

Central Nervous System

Brain

Man stands unique and supreme in the living world and this supremacy is due to a highly developed brain. It is very well developed resulting in high mental capacity. The brain and the spinal cord are protected by three coverings called *meninges* and a hard bony skull, the *cranium*, which gives additional protection. The brain of an adult man weighs about 1.4 kg.

The brain has three primary divisions, the *forebrain*, the *midbrain* and the *hindbrain* (Fig. 3.3 AB). The forebrain consists of the *cerebrum* and *diencephalon*. The cerebrum is the largest part of the human brain and covers almost all other parts. It consists of two lobes, the right and left *cerebral hemispheres* separated by a deep groove. The cerebrum is composed of two regions an outer *cortex* and an inner

medulla. The cortex is composed of nerve cell bodies and forms the *grey matter*. The medulla is composed of nerve fibres (axons and dendrites) and forms the *white matter*

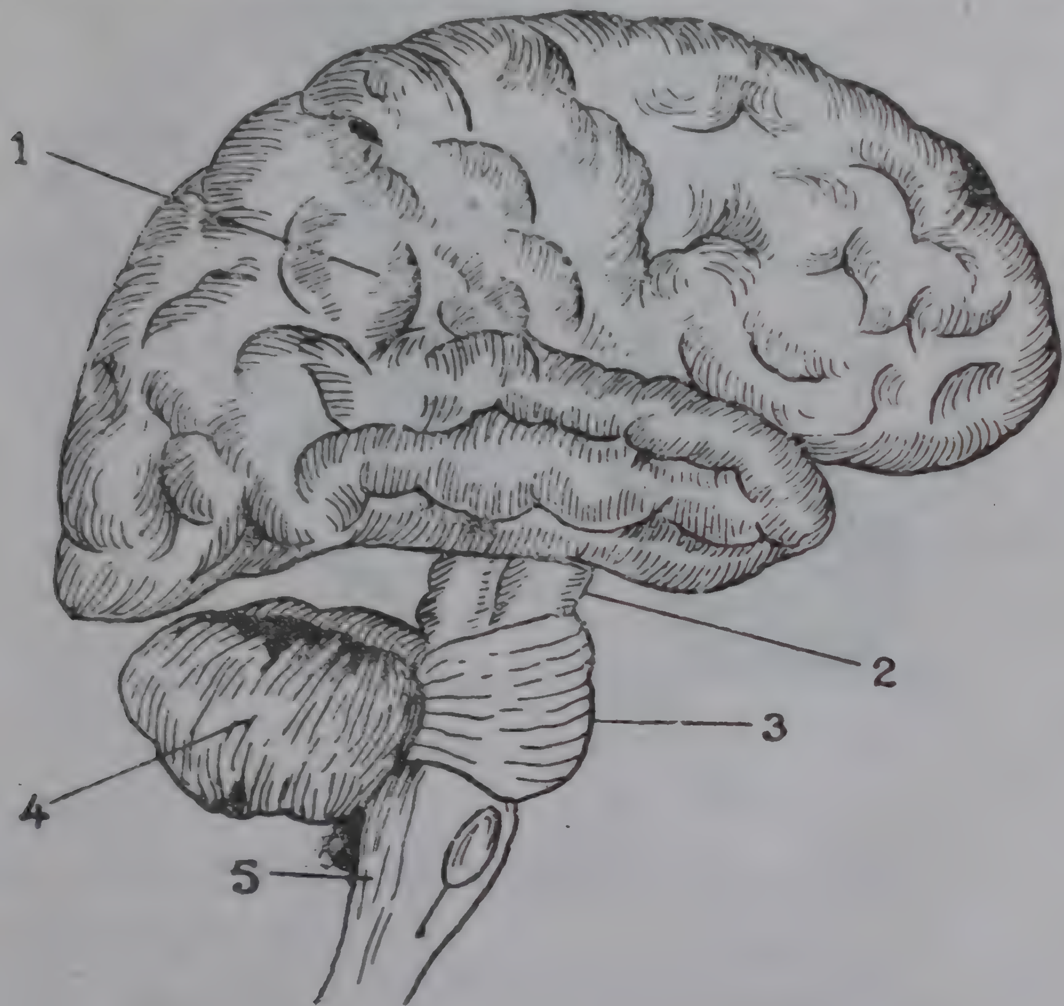


Fig. 3.3 (A). Human Brain (Stretched to show parts)

1. Cerebrum
2. Mid brain
3 Pons
4. Cerebellum
5. Medulla oblongata

The cortex is deeply folded into ridges called *convolutions*. These convolutions increase the surface area of the cerebrum. The cerebrum is the seat of consciousness, intelligence, memory, imagination, reasoning, emotions and will. Specific areas of the cerebrum are associated with specific functions. Thus there are separate centres for hearing, seeing, tasting, speaking and so on (Fig. 3.4) Damage to a particular centre affects a particular faculty.

The diencephalon is anterior to the midbrain. It can be divided into dorsal *epithalamus*, middle *thalamus* and ventral *hypothalamus*. The thalamus receives nerve impulses

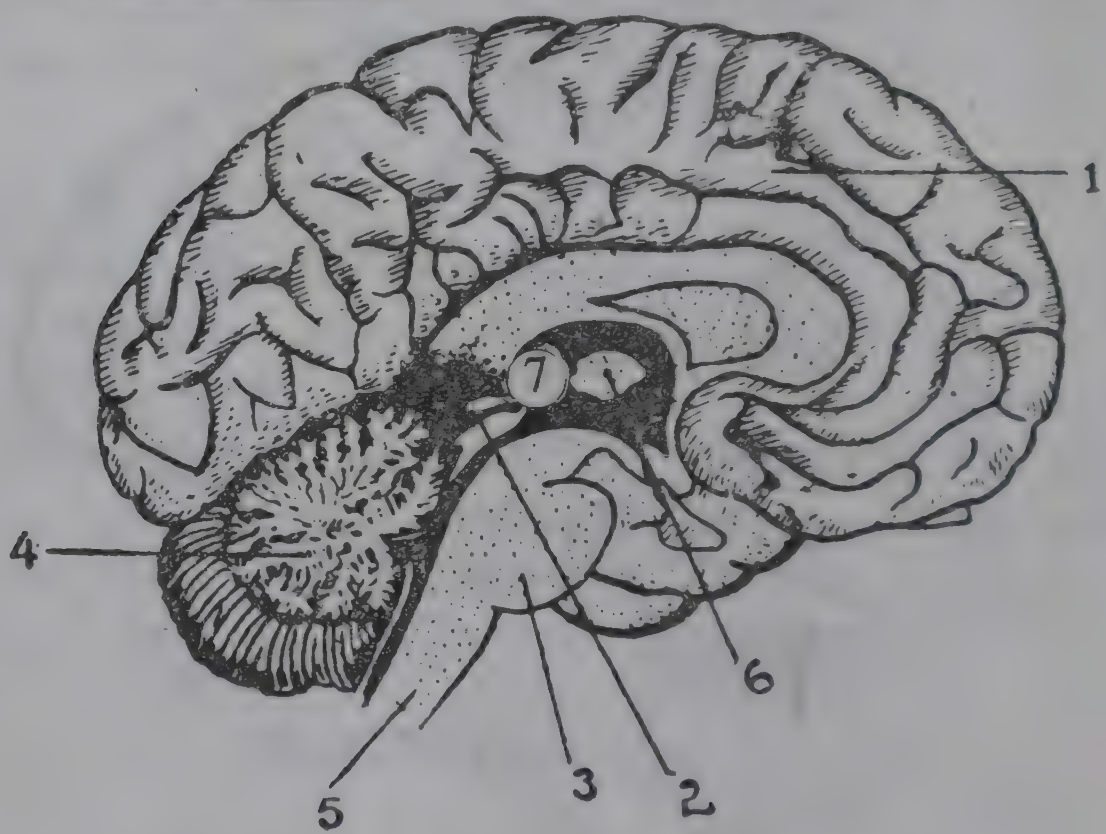


Fig. 3.3 (B). Section of the Human Brain

1. Cerebrum
2. Mid brain
3. Pons
4. Cerebellum
5. Medulla oblongata
6. Thalamus
7. Hypothalamus

from many sense organs. The hypothalamus regulates body temperature, water balance, appetite, sleep etc. It also controls the autonomic nervous system.

The midbrain is a small portion of the brain made up of nerve fibres connecting the forebrain and the hindbrain, that is, the *cerebrum* and the *cerebellum*. It serves mainly as a relay station through which impulses move from the hindbrain to the forebrain. It is concerned with many impulses coming from the eyes and ears.

The hindbrain consists of *pons*, *cerebellum* and the *medulla oblongata*. Pons is the conducting medium

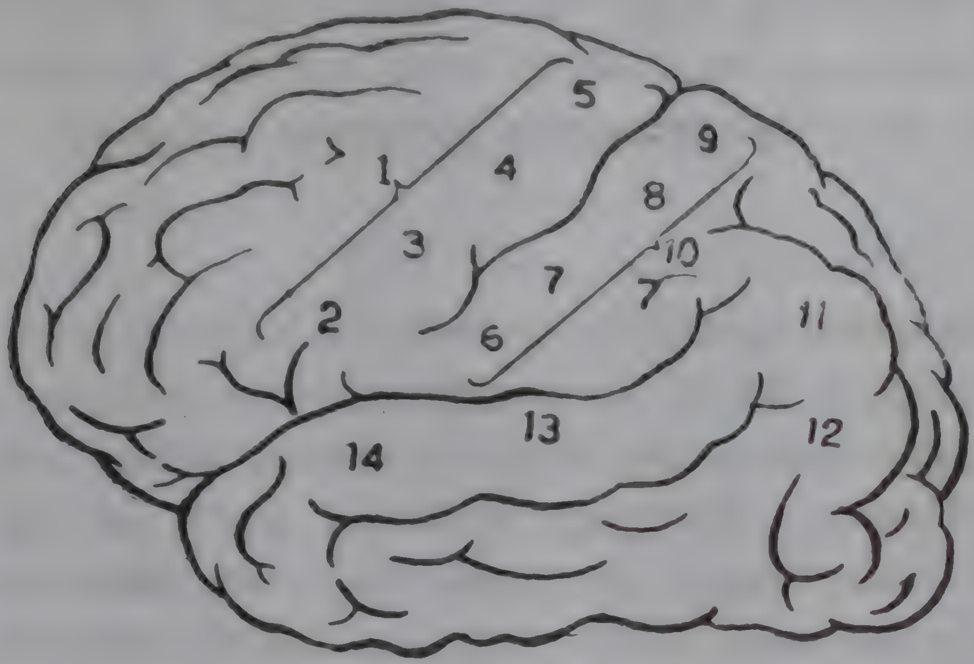


Fig. 3.4. Areas of Sensation on Cortex Region

1. Motor Areas 2. Head 3. Arms 4. Trunk 5. Legs
6. Head 7. Arms 8. Trunk 9. Legs
10. Sensory Areas 11. Visual Speech 12. Vision
13. Auditory speech 14. Hearing

between cerebrum, cerebellum and medulla. It has the controlling centres of mastication, facial expression, respiration and forms the conduction pathway. There are 12 pairs of cranial nerves in man of which four pairs originate from the pons.

Cerebellum lies below and behind the cerebrum. The grey matter lies outside and the white matter lies inside the cerebellum. It regulates and co-ordinates the movements of muscles in actions like walking or running. In other words cerebellum is concerned with the maintenance of equilibrium and the co-ordination of the contraction and relaxation of the muscles.

3

Medulla oblongata is the posterior most region of the brain which continues into the trunk as the spinal cord. It has centres to control the involuntary activities of the body such as breathing, heart beat, movements of the digestive tract (vomiting, swallowing etc.), enzyme secretion, blood pressure and other important metabolic activities.

Spinal Cord

The spinal cord is composed of a large number of nerve cells and nerve fibres. It co-ordinates the movements of the limbs and organs in the body by reflex action. It has 31 pairs of nerves supplying different parts of the body, namely heart, lungs, stomach, pancreas, adrenals, small and large intestines, kidneys, urinary bladder and sex glands. It has the grey matter in the centre and the white matter surrounding it. The spinal nerves are made up of both sensory and motor nerve fibres (Fig. 3.5).

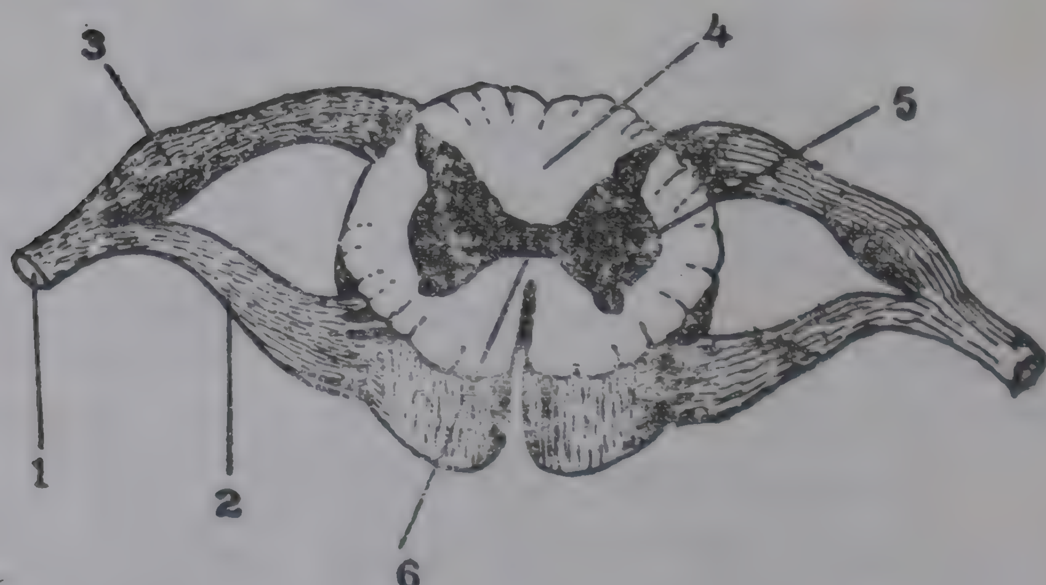


Fig. 3.5. Cross Section of the Spinal Cord

1. Spinal nerve 2. Ventral root 3. Dorsal root (with ganglion)
4. White matter 5. Grey matter 6. Central canal.

Peripheral Nervous System

Peripheral nervous system consists of 12 pairs of cranial nerves arising from the brain and 31 pairs of spinal nerves arising from the spinal cord.

Cranial nerves originate in different parts of the brain and are connected principally to the sense organs, muscles and glands in the head. Some of them such as optic and auditory nerves are purely sensory while some are motor nerves. The remaining are mixed nerves, being both sensory and motor in function. One of the most important cranial *nerve*, the *vagus*, forms a part of the autonomic nervous system and gives out branches to the heart, lungs and the digestive organs.

Autonomic Nervous System

The heart, lungs, digestive tract and other internal organs are connected by a special set of peripheral nerves, collectively called the *autonomic nervous system*. The autonomic nervous system is entirely automatic and involuntary in function. It is composed of two parts, namely, the *sympathetic* and *parasympathetic* systems with opposite actions. If one increases a particular activity the other decreases it.

The sympathetic system consist of a double chain of ganglia, one on each side of the spinal cord. Anteriorly the nerve chain joins the tenth cranial nerve. Along its length it is connected to the spinal nerve. From the ganglia, nerves branch off to kidneys, intestine, stomach, liver and other internal organs (Fig. 3.6). This system helps to regulate actions of the heart, the secretion of hormones, flow

of blood in the arteries, and the action of the smooth muscles of the stomach and intestines.

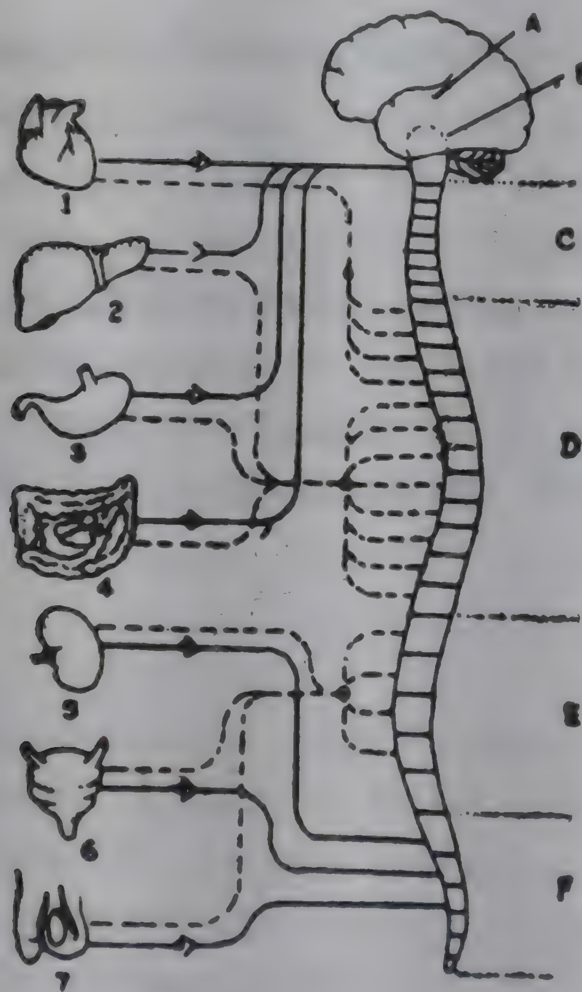


Fig. 3.6. Some of the Motor pathways of Autonomic Nervous System. (Sympathetic ...... Parasympathetic........)

A. Hypothalamus, B. Medulla, C. Cervical region, D. Thoracic region, E. Lumbar region F. Sacral region.

1. Heart 2. Liver 3. Stomach 4. Intestine 5. Kidney 6. Urinary Bladder 7. External genitalia.

The parasympathetic system starts from the 3rd, 7th, 9th and 10th cranial nerves and the spinal cord. Impulses from the sympathetic and parasympathetic fibres always have opposite effects on the organs. For example, the sympathetic system stimulates the pupil in the eye to dilate whereas the parasympathetic system causes it to constrict.

A reflex action is an automatic response to a stimulus. The spinal cord is the centre of such reflex actions. (For more details see chapter on Animal Behaviour). If we step on a sharp object, we respond immediately by jerking our foot away from the object; we do not wait till the pain is recorded by the brain and then decide what to do.

The pathway of the nerve impulse from the time of stimulus to that of response is termed as *reflex arc* (Fig. 3.7). It consists of five distinct parts. (1) A *receptor* (sense organ)

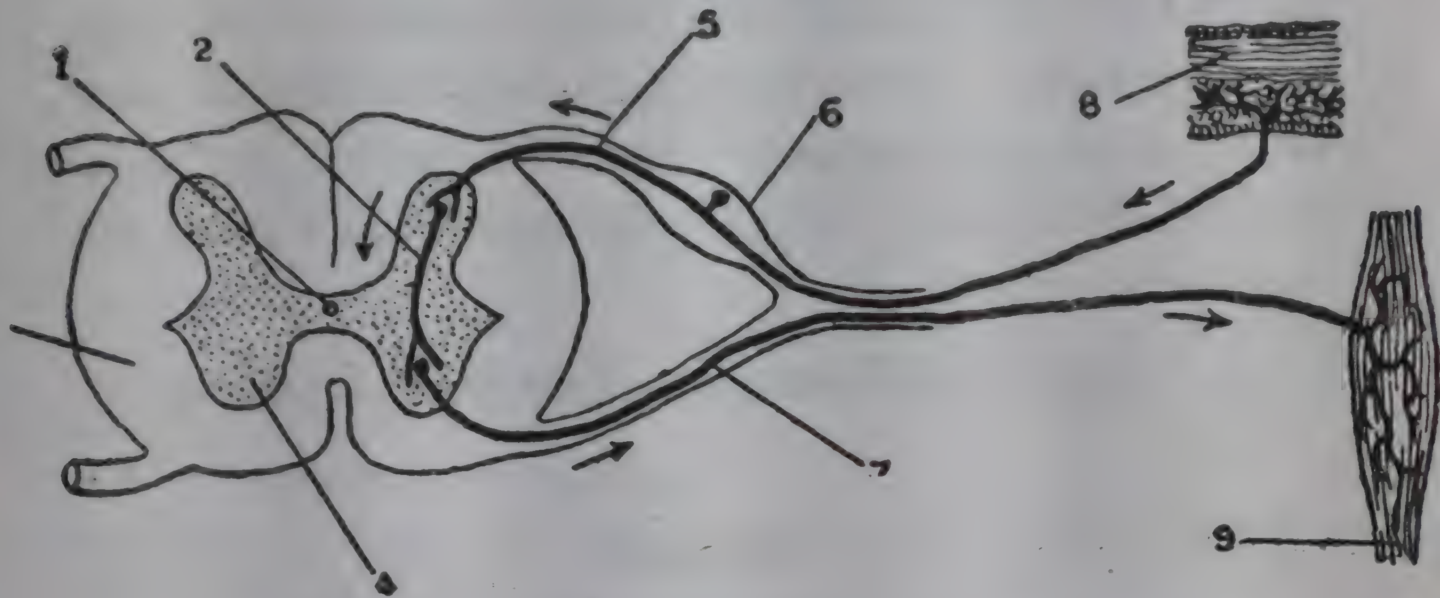


Fig. 3.7. The Reflex Arc

1. Neural canal
2. Association neuron
3. White matter
4. Grey matter
5. Afferent neuron
6. Dorsal root ganglion
7. Efferent neuron
8. Receptors in skin.
9. Effector (muscle)

that receives the stimulus, (2) a *sensory neuron* that conducts the impulse from the receptor to the spinal cord or the hindbrain, (3) an *association neuron* which transmits the impulse from the sensory neuron to (4) a *motor neuron* through which the impulses pass on to (5) an *effector* where the action in response to the stimulus takes place. Except higher centres of the brain situated within the cerebrum, any other part of the central nervous system can act as a reflex centre. This explains why reflex actions are unconscious actions. Reflex actions involving the spinal cord are called *spinal reflexes* and those involving the brain are called *cranial reflexes.*

At Home

1. Sit down and cross the right leg over the left so that the left knee fits in behind the right knee joint and the right leg hangs freely. Strike the right leg with the edge of your hand just below the kneecap. Note that the left leg jerks forward and upward. This is reflex action and is called the ' knee-jerk ' reflex.

2. Study the different parts of the brain of a sheep.

Questions

1. What are the differences between the nervous system in invertebrates and vertebrates ?
2. Name the parts of the central nervous system.
3. Which are the important parts of the human brain ? State one function of each part.
4. Draw a neat diagram of the vertical section of the human brain and label the parts.
5. What is reflex action ? Explain with an example.
6. Draw a neat diagram of the cross section of the spinal cord and label the parts.
7. Distinguish between :
   (1) Receptor and effector.
   (2) Sensory nerve and motor nerve.
   (3) Sympathetic and parasympathetic system.
   (4) Neuron and nerve.
8. What are cranial nerves ? To which part of the body they are connected ?

II. Fill in the blanks ;

(1) 10 pairs of spinal nerves are there in frog.

(2) Midbrain connect the forebrain and hind brain.

(3) Medulla oblongata is the part of the brain which continues as spinal cord.

(4) Vagus form the part of peripheral nervous system.

III. Name the following :

1. The collar like structure that encircles the pharynx of the earthworm. — Circumpharyngeal

2. The tenth cranial nerve. Vagus

3. The part of the brain concerned with the balance of the body. Cerebellum

4. Reflex action involving the brain. Cranial refl

IV. Give reasons for the following :

1. After getting down from a merry-go-round, we feel confused.

2. Cerebrum is the seat of consciousness.

3. Drunkard walks unsteadily.

4. The spinal nerves are mixed nerves. The spinal nerves made up of both sensory & motor ne

* * * *

CHAPTER 4

Sense Organs

The environment in which we live influences our life. It is therefore essential for our body to sense any change in the environment in order to adjust to the change. Such changes are detected by the sense organs and communicated to the *central nervous system*, which issues suitable orders to the body to make the necessary adjustments. The sense organs receive stimuli and pass the message to the brain, and the brain interprets the message. Our five senses are vision, hearing, smell, taste and touch. The five sense organs are eyes, ears, nose, tongue and skin. The sense organs possess receptors which can receive various types of stimuli and convert them into electrical impulse. In the eye light energy is converted into electrical energy by receptor cells and transmitted to the brain. In the ear, the mechanical energy of the sound waves is converted into electrical energy by the receptor cells. In the nose the impact of odourous particles are changed into electrical energy. In the tongue the chemical stimulus is changed into an electrical impulse. In the skin the contact stimulus is converted into an electrical impulse.

The Eye

The eyes are the organs of sight and are stimulated by light. They are highly specialized and sensitive to light. They can adjust themselves to see any object. As long as your eyes are open they go on visualizing and carrying impressions as pictures. The eyes have many accessory parts whose main function is protection. The eyebrows protect the eye

from small particles that fall from above the eye. The hairs of the eyebrows help to shade the eyes from bright illumination. The upper and the lower eyelids are folds of skin, each provided with eyelashes, protect the eyes and keep them moist. They can close rapidly to prevent dust or other things from entering the eyes. A thin transparent membrane called the conjunctiva lines the inner wall of the eyelids as well as the front of the eye. Tear *glands or lachrymal glands* situated in the inner region of the upper eyelid produce secretions (tears) to keep the surface of the eye moist and wash out dirt and other foreign particles. It contains salt and is also antiseptic. Thus it helps to reduce the danger of eye infections. The excess of tears pass through ducts into the nasal cavity. Each eye is provided with three pairs of muscles, the contractions of which cause the movement of the eye in different directions.

Structure of the Eye

The wall of the eye consists essentially of three layers *sclera, choroid* and *retina* (Fig. 4.1). The outer most layer,

1. Cornea
2. Aqueous humour
3. Pupil 4. Lens
5. Iris
6. Suspensory Ligament
7. Sclera 8. Choroid
9. Retina
10. Optic Nerve
11. Vitreous Humour
12. Fovea (yellow spot)
13. Blind spot
14. Conjunctiva

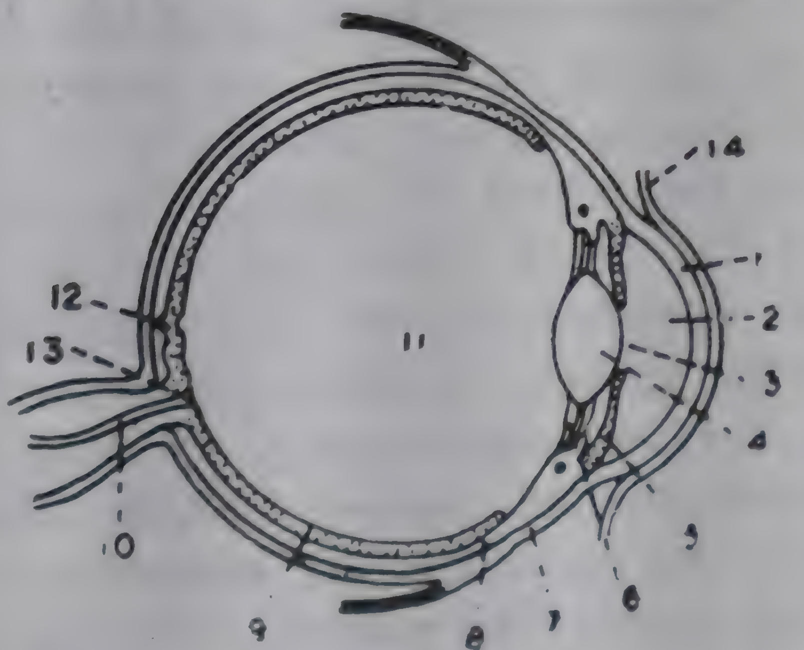


Fig. 4.1 Vertical section of the Human Eye

called the sclera, is visible as the white outer covering of the eye. Being composed of fibrous connective tissues it is tough, opaque and protective. It helps to maintain the shape of the eyeball. In front, this layer is bulged, transparent and forms the cornea through which light enters. The curved surface of the cornea acts as the outer lens of the eye. Cornea can be stored and grafted on to another person.

The second (middle) layer is the choroid which forms the inner lining to the opaque portion of the sclera. It is a thin and black layer (cells filled with black pigment) which is richly supplied with nerves and blood vessels. It not only nourishes the eye but also prevents the reflection of the extra light within the eye by absorbing it. In the front part of the eye, this layer becomes modified to form the *iris*. The iris hangs down like a diaphragm in front of the eye with a central opening called *pupil*. The size of the pupil is controlled by the muscles of the iris. The colour of the eye such as brown, grey, blue, green is partly due to the pigment in the iris and partly due to the diffraction of light by the iris. The *lens* is transparent and biconvex and lies behind the pupil. The lens focuses light rays on the retina. With the help of the ciliary muscles the curvature of the lens can be increased to focus nearer objects. Between the cornea and the lens there is a space called anterior chamber and is filled with a watery fluid, the *aqueous humour*. The large cavity behind the lens is called the posterior chamber and is filled with a jelly like material, the *vitreous humour*, which has the consistency of raw egg albumen. These fluids, filling the cavities of the eye, refract light rays and maintain

a pressure within the eyes, keeping the layers in position and preventing the eye from collapsing.

The third and the innermost layer is the *retina*, the light-sensitive portion of the eye. The image falls on this which acts as a screen. It contains numerous receptors and nerve fibres. Receptors convert light into impulses. These receptors are special cells called *rods* and *cones* (Fig. 4.2). Each eye contains numerous rods which are

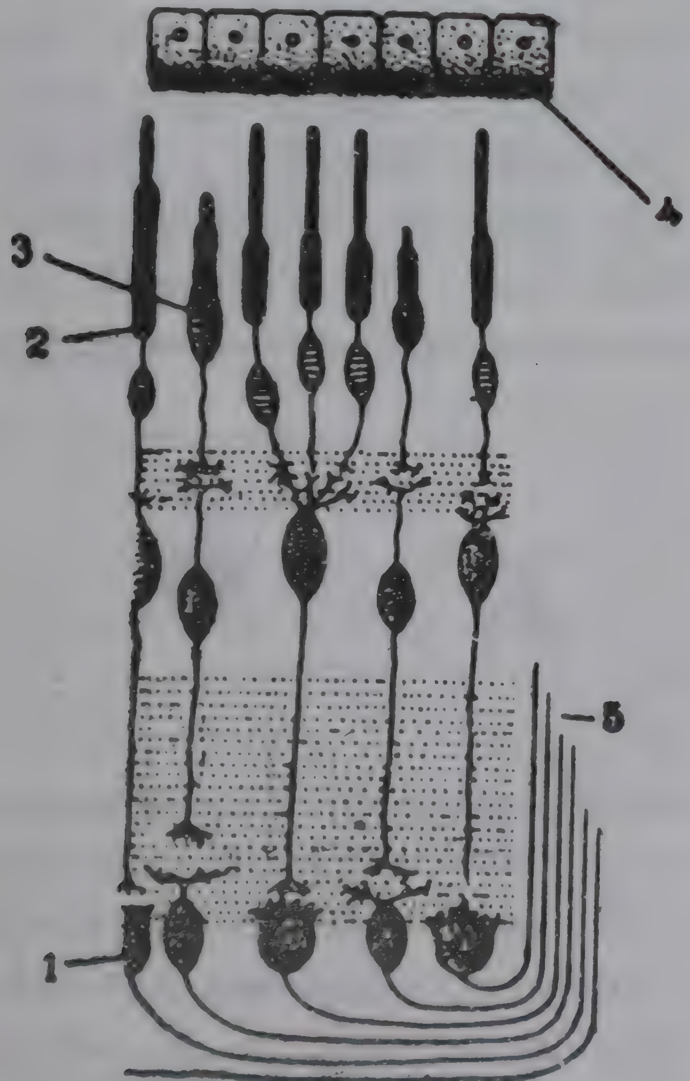


Fig. 4.2. A portion of the retina enlarged to show the nerves, rods, cones and pigment cells in choroid.
1. Nerve Cell, 2. Rod, 3. Cone,
4. Pigment, 5. Optic Nerve.

found mostly on the periphery of the retina. They ar sensitive to dimlight and so do not distinguish colours Each eye also contains cones which are sensitive to brigh light and can distinguish colours. The cones are mor in number at the back of the eye opposite to the pupil This part is somewhat depressed and is known as the *yellow* spot or *fovea*; vision is sharpest here. The nerve fibre starting from these receptors of light, come out of the eyebal in the form of a single nerve called the *optic nerve.* Thi emerges from the back of the eye a little below the fovea Where the optic nerve leaves the eye, the retina has no rod and cones and consequently images fallirg in this area canno be perceived. This area is therefore called the *blind spo* The blind spot can easily be located by means of a simpl experiment. Close your left eye and look steadily with th

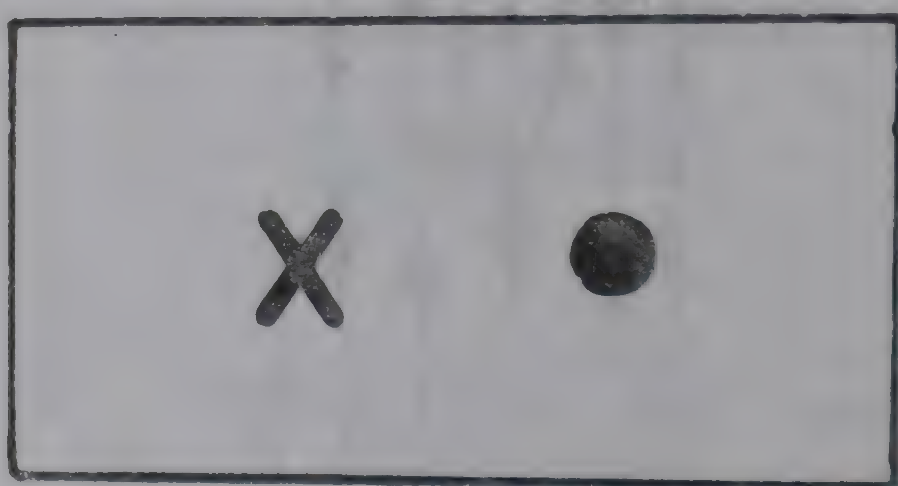


Fig. 4.3. How to locate blind spot in the eye

right one at the *cross* on the left side of the figure. No move the book slowly backwards and forwards at the le of the eye. At a certain point the *dot* will disappear fro vision. This is because its image falls on the 'blind spo

How does the eye work?

The working of the eye can be compared to that o camera. Light is essential for seeing an object as for tak

a photograph. Light reflected from an object enters the eye through the pupil, the size of which is regulated by the contraction of the muscles in the iris. The automatic adjustment regulates the intensity of light that enters the eye. Light rays refracted by the cornea, aqueous humour, the lens and the vitreous humour converge on retina and form an image which is inverted and reduced in size. The muscles of the eye ball move in such a way so as to make the images fall on the yellow spot where vision is sharp. The retinal cells exposed to the light in the region of the image are stimulated by photochemical reactions. These cells convert the stimulations into electrical impulses which pass along the optic nerve to the *visual centre* in the cerebrum. The interpretation of these impulses in the visual centre of the cerebrum results in vision.

How do you see near and far objects?

In a photographic camera, the lens is moved back and forth to focus the image of objects at varying distances on the photographic film or plate. The human eye, however, adjusts itself to near and far objects by altering the focal length of the lens. When the lens focuses the image of a nearby object, the muscles around the lens contract and the convexity of the lens increases. When we are seeing a distant object, the convexity of the lens decreases and becomes flattened. This adjustability of the lens is called *accommodation.*

Defects of vision and its correction

The shape of a normal eye is such that the retina lies at the correct distance behind the lens for the light rays to converge and form a clear image on it. (Fig. 4.4). In a

normal eye the image is focused on the retina. The shape of the eyeball is maintained by the sclera as well as by fluids that fill the cavities of the eye. An improper blood

Fig. 4.4. Normal Eye.

supply to the eye and other factors may bring about a change in the shape of the eyeball. resulting in defects of vision. The common defects of vision are *short-sightedness* and *far-sightedness.*

Short sightedness or Myopia

Short sightedness may develop when the eyes are unduly strained. Faulty habits such as reading books by holding them very close to the eye or doing work with the material held close to the eyes under poor light may lead to this defect.

A short-sighted person can see objects if they are very close to his eyes. A myopic eyeball is longer than the normal eyeball (Fig. 4.5). The lens is normally thick and cannot become thin enough to form images of far off objects on the retina. Light rays converge or focus at a point in front of the retina. They therefore diverge when they fall on the retina and so form a blurred image on it. This defect is corrected by using a concave lens of

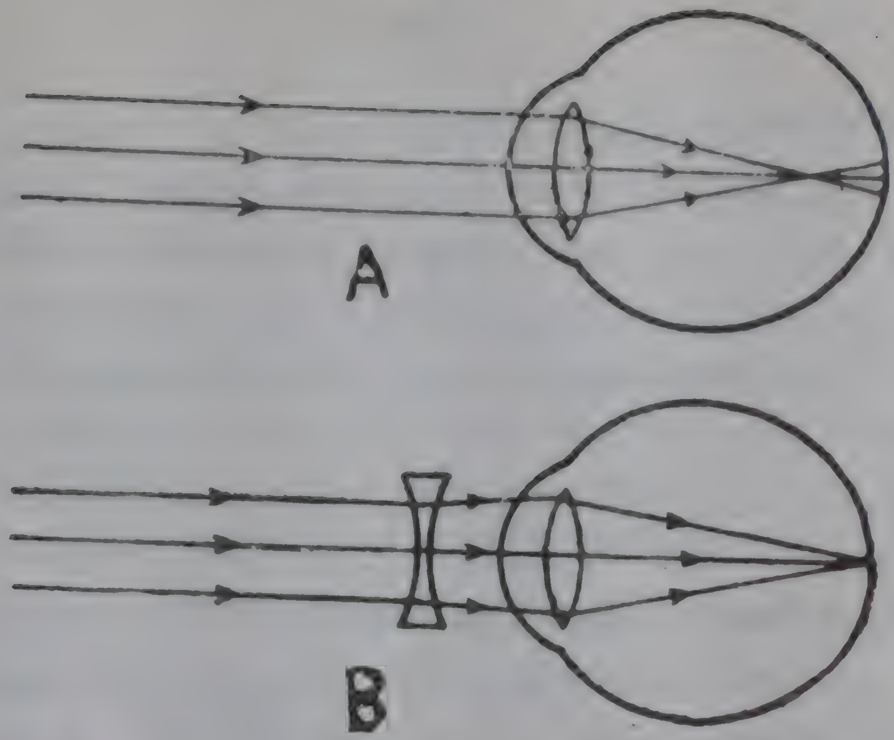


Fig. 4.5. A. B. Myopia and its correction
A. Myopia B. Myopia corrected.

an appropriate power which will *diverge* the light before they enter the eye. The lens of the eye will now focus the diverged rays so as to form a sharp image on the retina (Fig. 4.5 B).

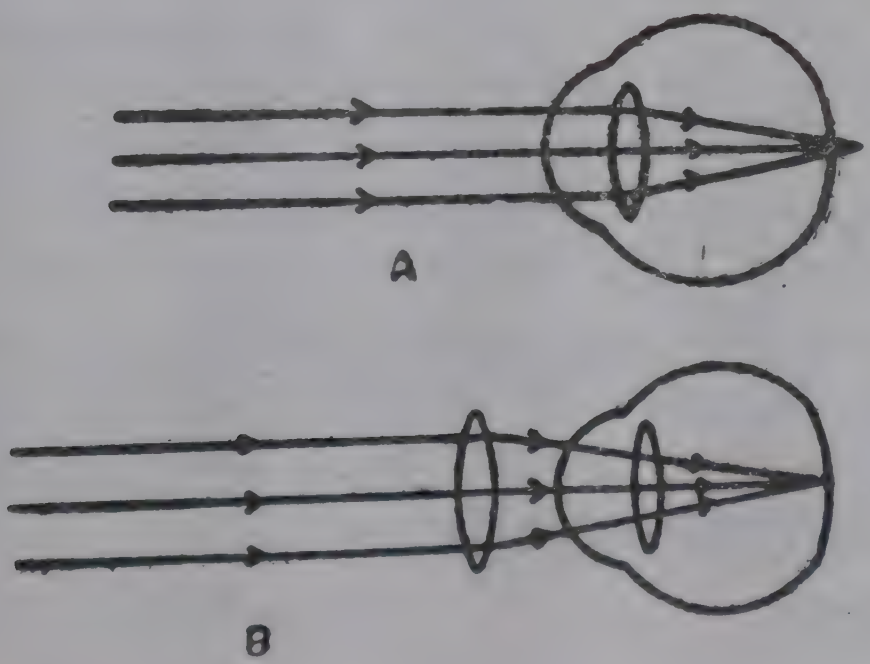


Fig. 4.6. A. B. Hyper metropia and its correction
A. Hyper metropia B. Hyper metropia corrected.

Far sightedness or Hyper-metropia

The eye ball in the farsighted person is abnormally short. In this case the image of the objects is formed far behind the retina (Fig. 4.6 A). The result is a blurred image. Accommodation helps to bring the image of a distant object into focus on the retina and so one can see the distant object clearly. But this imposes a strain on the eye. Near-by objects cannot be focused on the retina even after accommodation. This defect is corrected by using a convex lens of a suitable power so as to *converge* the light rays to form the image on the retina (Fig. 4.6 B). In old age the lens of the eye becomes somewhat rigid, so it cannot become convex enough to accommodate near vision. One uses convex glasses (reading glasses) to correct this defect.

Eye Grafting

In *cataract*, the lens of the eye becomes opaque due to a variety of causes. In the hands of a good surgeon, such a lens can be removed. An opaque cornea is even more serious. The only correction for this is the replacement of the opaque cornea with a cornea from a normal eye. This is a very delicate operation, but it is becoming more common. The cornea is unusual in that it can be transplanted from one person to another. As a result it is not uncommon now for people to will their corneas to others at the time of death, and in some centres "cornea banks" have been established.

Night Blindness

The rods are sensitive to dim light and contain a pigment called *rhodopsin* or *visual purple* which is formed from vitamin A. If the food does not contain enough of

vitamin A, one is unable to see in dim light. This defect is called *night blindness* and results from insufficient rhodopsin in the rods. Therefore, when there is bright light, the sight remains normal, but when it begins to get dark, a person suffering from this disease sees poorly.

Care of the Eyes

Precautions one should take to protect one's vision are:

(1) not to strain the eyes by reading in dim-light,

(2) avoid bright light falling directly into the eyes,

(3) read only where there is enough of light,

(4) rest the eyes every half an hour when one is doing close work, either by closing them or looking off into the distance for a few minutes,

(5) wash the eyes at least twice daily with clean water,

(6) have the vision checked frequently,

(7) consult an eye specialist whenever there is any trouble in the eyes.

You should always remember that the eyes you have are the only pair you will ever have.

The Ears

The ears are situated on either sides of the head and are responsible for hearing and in the balance of the body. Each ear consists of three parts, the *outer ear*, the *middle ear* and the *inner ear*. The inner ear is enclosed in a bony cavity in the skull (Fig. 4.7).

The outer (external) ear consists of the skin-covered cartilaginous *ear lobe* or *pinna*. It directs sound waves into the *auditory canal*. Pinna is present only in mammals. The

auditory canal has fine hairs at its opening that prevent foreign particles from entering the ear. The wax-secreting

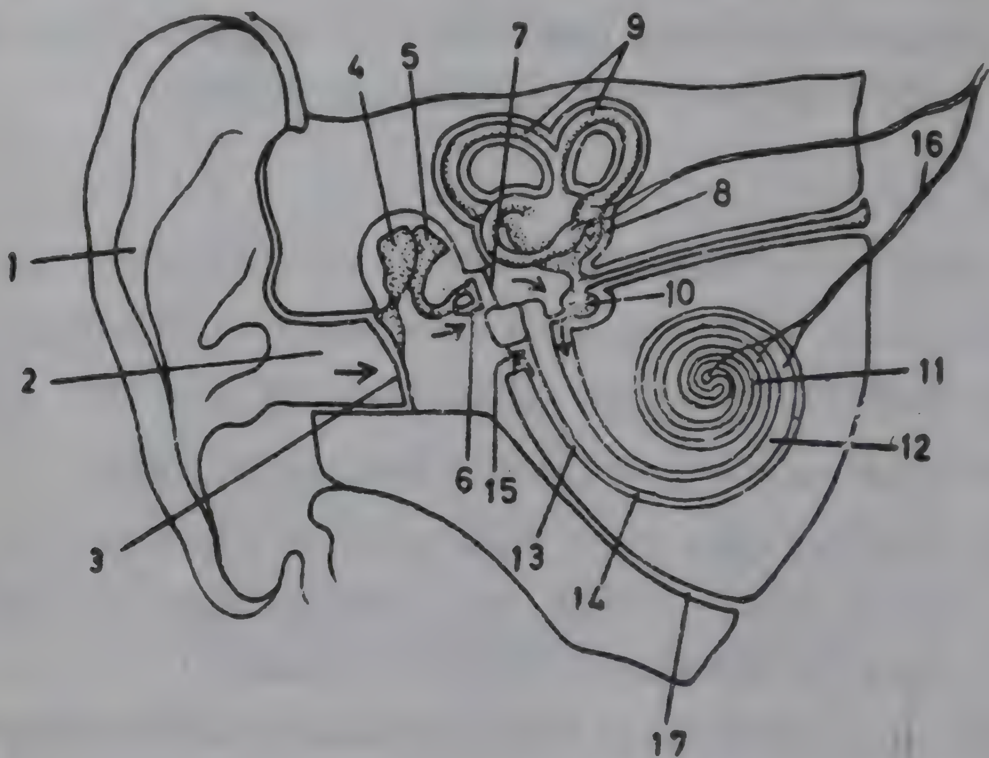


Fig. 4.7 The structure of the ear

1. External Ear. (Pinna) 2. Auditory canal 3. Ear drum (tympanum) 4. Malleus (hammer) 5. Incus (anvil) 6. Stapes (stirrup) 7. Oval Window 8. Utriculus 9. Semicircular canals 10. Sacculus 11. Cochlea 12. Organ of Corti 13. Perilymph 14. Endolymph 15. Round Window 16. Auditory Nerve 17. Eustachian tube

cells on the inner lining of the auditory canal produce wax which entangle small organisms and also dust. Thus the hairs and the waxy layer are protective in function. At the inner end of the auditory passage is an obliquely-placed membrane called the *eardrum* or *tympanum.*

The middle ear separates the outer and the inner ear. There are three small bones in the middle ear. The first bone, *malleus* is hammer-shaped and connects the eardrum with the second bone *incus.* Incus is anvil shaped and connects the malleus with the third bone *stapes* which is stirrup-shaped. Stapes is close to the *oval window* of the

inner ear, and its tip fits on to the oval window. The middle ear is connected to the throat by an air passage, the *eustachian tube.* This tube equalizes the air pressure on either side of the tympanum.

The inner ear or internal ear is the part where sound is perceived and is a delicate organ. The inner ear consists of two main parts, namely, *utriculus* and the *sacculus.* The upper part, the utriculus, is connected with three *semicircular canals.* These are placed at right angles to each other and help in sensing the balance of the body. The lower part of the sacculus has an appendage, the *cochlea.* The cochlea occupies much of the internal space and possesses a very delicate organ known as *the organ of Corti.* The receptors present in the organ of Corti join one another and form the *auditory nerve.* The whole inner ear is *surrounded by* a fluid called *perilymph* and is *filled with* a fluid called *endolymph.*

How do we hear sound ?

The sound waves are directed by the pinna to the ear drum through the auditory canal. The ear drum vibrates and these vibrations are carried to the inner ear through the chain of bones in the middle ear. The vibrations are conveyed to the perilymph. Since the cochlea is surrounded by the perilymph, the vibrations are conducted to the inner fluid, the endolymph, and to the organ of Corti of the cochlea. These wave impulses are picked up by receptors of the organ of Corti and are carried through the auditory nerve to the cerebrum, which is responsible for interpreting the sound. The act of hearing is brought about within a fraction of a second.

Care of the Ears

Wax is normally present in the auditory canal of the ears. Sometimes this gets hardened. It should not be removed by hard and sharp objects. These objects might injure the eardrum. A competent doctor can remove wax without any pain to the person.

Hearing can be damaged by loud noise. Working next to loud machines day after day, can make a person hard of hearing. Where one has to work near a place where loud noise is produced, it is wise to plug the ears with a bit of cotton or with ear plugs.

Deafness may result from injuries to any part of the hearing mechanism. Ear infections can also damage hearing. Germs which are present in the throat during a a cold may go up into the middle ear. If this happens the germs may grow in the middle ear and produce pressure on the eardrum, causing an earache. It is important that such people go to the doctor for treatment. These ear infections may cause permanent scarring of the eardrums and make a person hard of hearing.

Some individuals are born deaf because of malformations during development. It is very common for older people to become hard of hearing. A hearing aid often corrects the condition. A doctor gives advice on the use of a suitable hearing aid.

The Nose

Sense of smell is perceived through the nose. We are able to distinguish different types of smell. The nostrils lead into the nasal cavities which are lined by the *olfactory*

epithelium (Fig. 4.8). The receptors of smell are situated in the epithelial lining of the upper part of the nasal cavity. Molecules escaping from substances are carried by the inhaled air. On reaching the olfactory epithelium, they dissolve in the mucous and chemically stimulate the sensory cells. The stimulation is passed along the sensory neurons to the brain which interprets the message as the sensation of smell. Only certain molecules can stimulate the receptors. Those that do not are *odourless chemicals*. Sense of smell in man is not so well developed as in certain animals such as dogs.

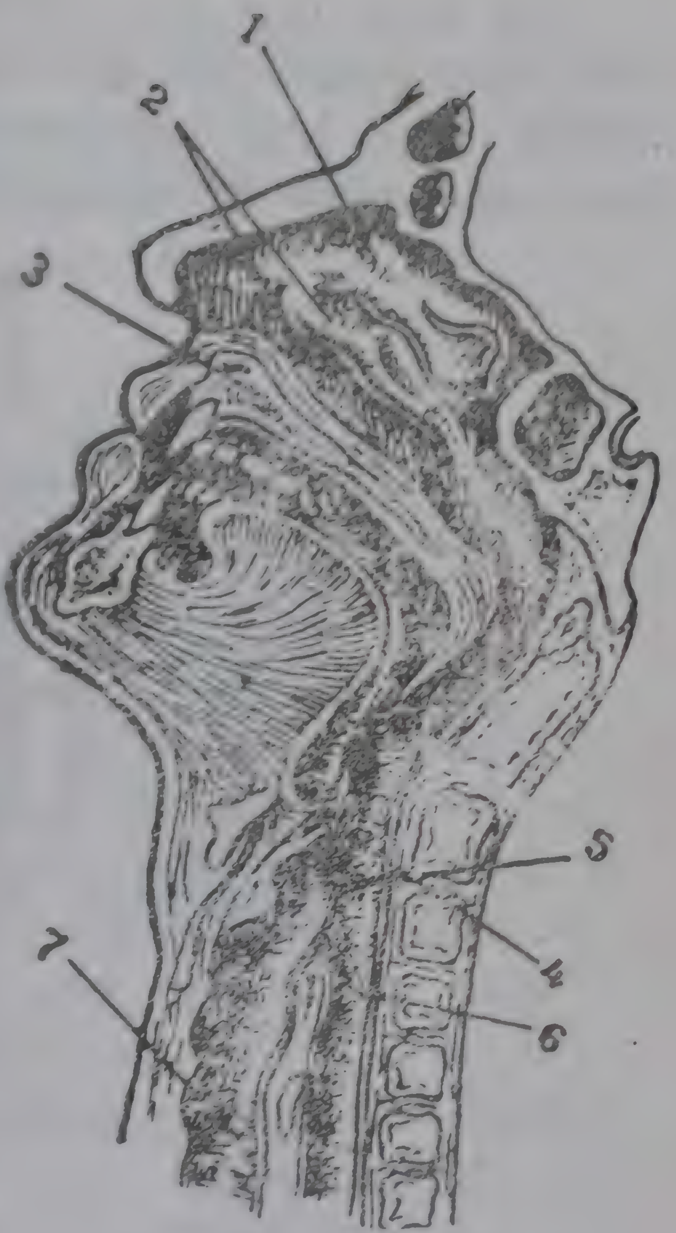


Fig. 4.8. Upper portion of the Respiratory Passage

1. Olfactory epithelium 2. Nasal chambers 3. Palate 4. Epiglottis 5. Pharynx 6. Oesophagus 7. Trachea

When one has a cold, food appears relatively tasteless because the sense of smell is partly or wholly lost owing to the inflammation of the olfactory epithelium.

The Tongue

The sense organs of taste are called the *taste buds*. They are embedded chiefly in the mucous membrane of the tongue. Each taste bud consists of a group of sensory cells surrounded by supporting cells (Fig. 4.9). The

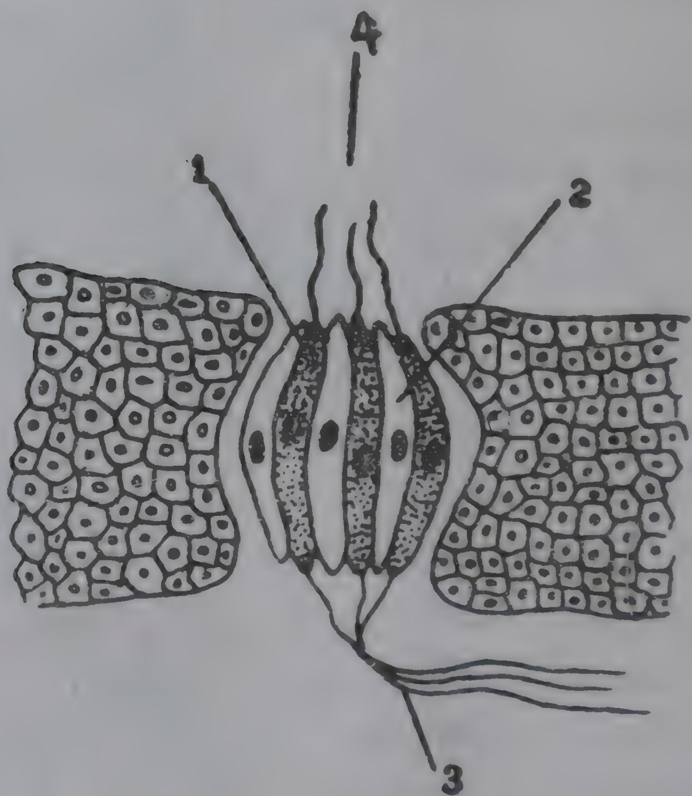


Fig. 4.9. A Taste Bud in the Tongue as seen in a Vertical Section.

1. Sensory cell
2. Supporting cell
3. To sensory neuron
4. Taste pore

supporting cells are connected to sensory neurons. Each taste bud opens on to the surface of the tongue by a small pore through which the cilia of the sensory cells project out.

Food dissolved in the saliva enters the pores of the taste buds and chemically stimulate the sensory cells. These cells convert these chemical stimuli into electrical impulses that pass along sensory neurons to the brain which interprets

these impulses as taste. There are different types of taste buds distributed unevenly over the surface of the tongue. This is the reason why different parts of the tongue are sensitive to different tastes. (Fig. 4.10).

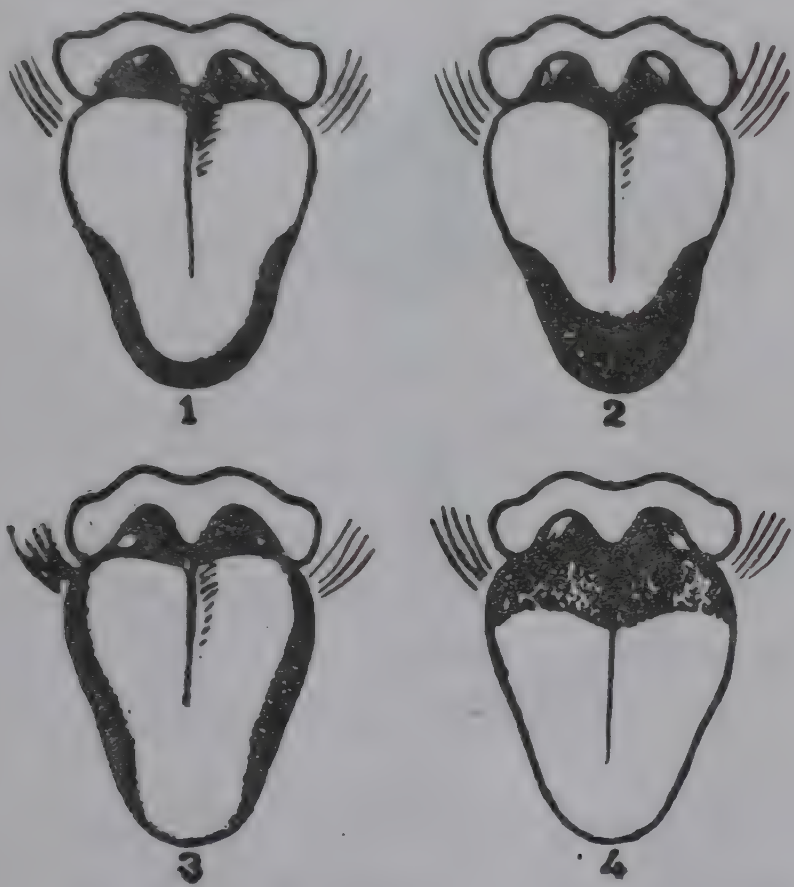


Fig. 4.10. Areas of taste on the tongue

1. Sweet 2. Salt 3. Sour 4. Bitter

There are four different types of taste. They are *sweet*, *salt*, *sour*, and *bitter*. The taste buds of sweetness are distributed in the front, those of the salt taste at the anterior margin, those of sour taste at the sides and those of bitter taste at the posterior region of the tongue. The sensation of pungency or 'hotness' of chillies and pepper is not due to any special buds but is due to general irritation of the epithelium on the tongue and mouth.

The Skin

You feel hot when you sit before an oven and feel cold when you move outside the house in winter. The pain of pricks, and of pressure is experienced by many parts of the bodv and mainly by the skin. (Fig. 4. ').

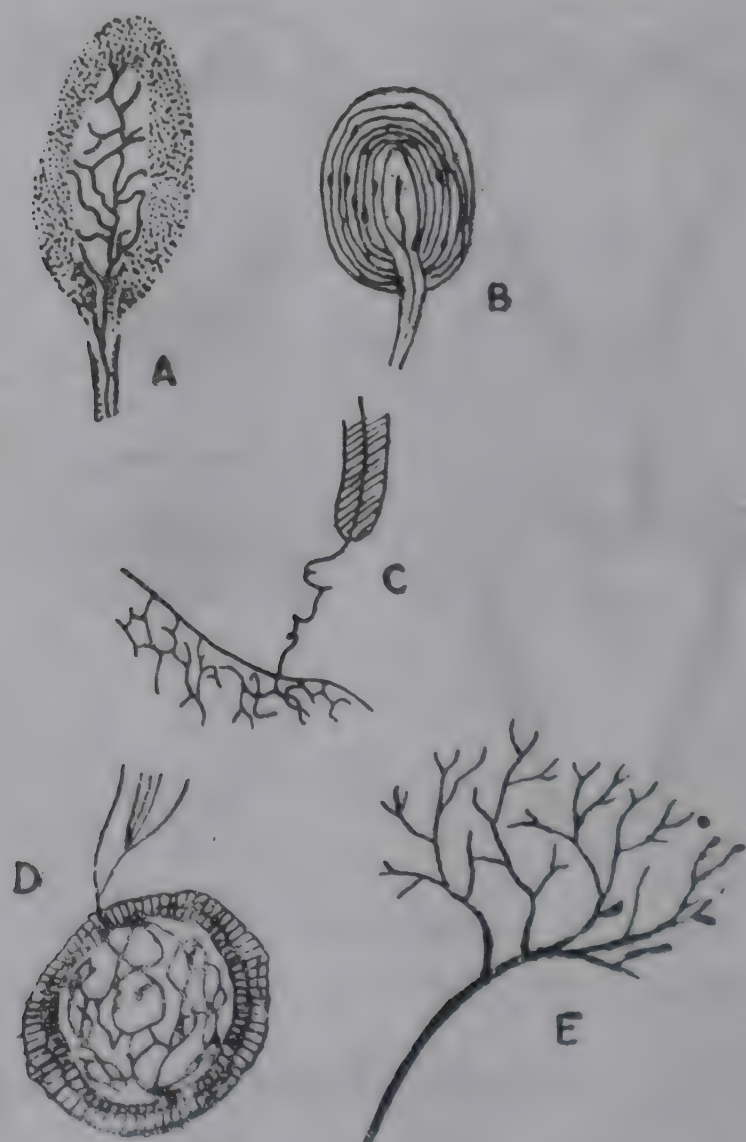


Fig. 4.11. Specialized Receptor Cells receiving different types of stimuli
A. Touch, B. Pressure, C. Heat, D. Cold, E. Pain

These sensations are received by nerve fibers originating from *receptors* and connect them to the brain, where they are interpreted to give the correct information. *Touch receptors* are near the surface of the skin. The *pressure receptors* are

deeper in the skin. We feel touch even by superficial contact and feel pressure only after pressing the finger heavily. The pain receptors are all over the body and are also deeply situated.

Care of the Skin

Keep your skin always clean. If you get some skin diseases like ringworm, consult a doctor immediately.

Things to do

1. Sit in a dimly lighted part of a room with your back to the window for a few seconds. Look at your eyes. in a mirror. Note the size of the pupils. Now go to a window and look out at the light for a few seconds. Note the size of your pupils again. This change in size of the pupils is the result of a reflex act. It is an automatic response over which you have no control.

2. Examine models, charts of the eye and ear. Learn to recognize the parts described. Study how these parts work together.

Questions

I. 1. Name the sense organs of man.

2. Draw a neat diagram of the vertical section of the human eye?

3. How is the human eye adapted for near and far vision ?

4. Distinguish between yellow spot and blind spot.

5. What is the function of cones and rods ?

6. What is short sight (myopia) ? How is it caused ? And how can it be corrected ?

7. Explain how we hear sound ?
8. Name the parts of the middle ear. Explain the function of each part.

II. Fill in the blanks :

1. Pupil .... is the opening present in the centre of the iris.
2. In Cataract .... disease, the lens of the eye becomes opaque.
3. Rods and cones are present in .... Retina
4. Rods contain a pigment called .... Rhodopsin
5. Semi circular canals .... present in the ear helps in balancing the body.
6. The pressure receptors are deeper .... in the skin.

III. Name the following :

1. Transparent covering in front of the eye. Cornea
2. The outermost layer of the eye. Sclera
3. The part of the eye which helps in the power of accommodation. Lens
4. Cones, Rods The receptors present on the retina of the eye.
5. The nerve which arises from the eye ball. optic nerve
6. The fluid which surrounds the inner ear. perilymph
7. The organ which converts sound waves into electrical impulses. Cochlea

* * * *

CHAPTER 5

The Ductless Glands

You have studied several glands already. You know how saliva, gastric juice, pancreatic juice and bile are produced by glands. A gland is an organ whose cells are specialised for producing a particular secretion. Some times a highly specialized single cell constitutes a gland. This secretion flows out of the gland through a duct or opening. In this chapter you will study a special group of glands situated in different parts of the human body. Since these glands do not have ducts to carry their secretions, they are called *ductless glands or endocrine glands.* The secretions of the endocrine glands are called *hormones.* These are introduced directly into the blood stream.

A hormone is a chemical substance secreted by cells in one part of the body and carried by the blood to some other part called *target organ* where it is effective in regulating and coordinating the activities of the cells. Since hormone carries a stimulus from one part of the body to another, it is often referred to as a *chemical messenger.* All the hormones that have been identified chemically are either proteins, amino acids, amines or steroid compounds. (Steroid compounds are a group of fat-soluble compounds. They play an important role in cell metabolism. In man steroids are formed from a substance called *cholesterol* which is carried by the blood).

Hormones are produced in minute quantities and even in small concentrations they are effective. If there is excess secretion of any particular hormone it leads to *hyperfunction*, an inadequate secretion leads to *hypofunction*

of the target organ. In the rest of this chapter you will learn about some of the better known hormones and of the glands that produce them. As you read about each gland, locate it in Fig. 5.1.

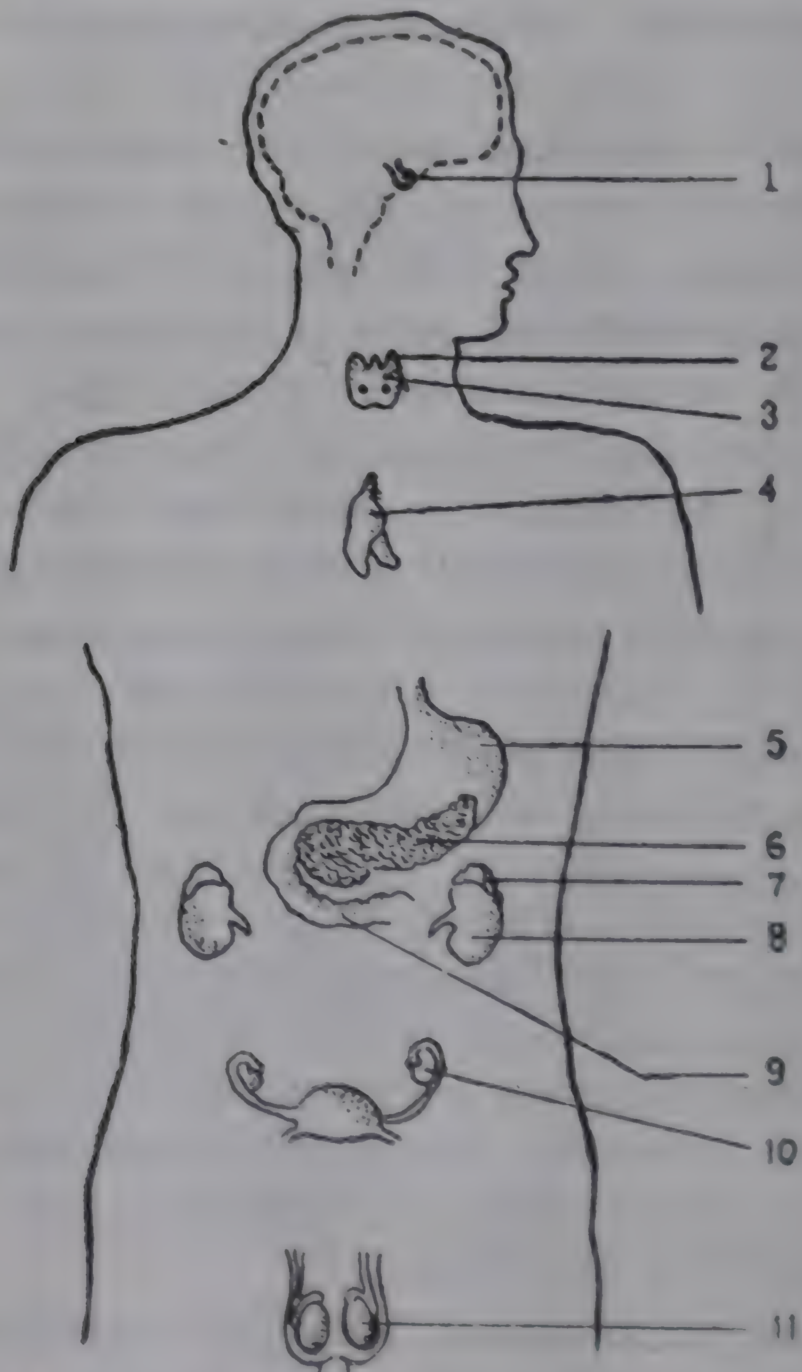


Fig. 5.1 Diagram showing the location of major endocrine glands in the body of man

1. Pituitary	2. Thyroid	3. Parathyroid
4. Thymus	5. Stomach	6. Pancreas
7. Adrenal	8 Kidney	9. Duodenum
10. Ovary (female)	11. Testis (male)	

The important endocrine glands are *pituitary, thyroid parathyroid, adrenals, islets of langerhans* and the *gonads* (reproductive glands).

The Pituitary Gland

The pituitary gland is embedded at the base of the brain. It is the size of a pea. This gland secretes several hormones, some of which have control over other endocrine glands. Some of the functions of the pituitary are controlled by the hypothalamus. The pituitary consists of anterior, middle and a posterior lobes.

The following are the function of each one of the pituitary hormones :

1. Influences the rate of growth of the body.

2. Influences the secretion of the hormone from the thyroid gland (thyroxin).

3. Influences the activity of the adrenal gland.

4. Influences the secretion of milk by the mammary glands.

5. Influences the excretion of water from the kidneys.

6. Influences the contraction of muscles of the uterus.

7. Influences the development of the ovary and testes and the secretion of steroid hormones from the gonads.

If a pituitary hormone (called growth hormone) is over secreted before puberty, the individual grows gigantic in

Fig. 5.2. Abnormalities of Pituitary Hormone.
A. Hypersecretion
B. Hyposecretion

size. If there is under-secretion the individual becomes a dwarf (Fig. 5.2). The over-functioning of the hormone in adult may also results in a disease known as *acromegaly* causing disproportionate growth of bones particularly jaws, nose, hands and legs.

When the posterior portions of the pituitary glands is in disorder, a disease known as *diabetes insipidus* appears. The patient passes out by way of the kidneys large quantities of dilute urine.

The Thyroid Gland

The thyroid gland is situated in front of the trachea below the throat (Fig. 5.3). It consists of a pair of lobes connected by a narrow strip of the same tissue. The gland is brownish-red in colour and is richly supplied with blood vessels. It secretes a hormone called *thyroxin*. It is an amino acid in combination with iodine. Thyroxin speeds up the rate of metabolism of the body. It regulates the rate of oxidation of substances. It is therefore essential for normal growth and development, particularly that of the skeletal and nervous systems. A defect in the functioning of the thyroid gland may result in

decrease or increase in the production of thyroxin. This is often accompanied by abnormalities which may be classified under two heads *hypothyroidism* and *hyperthyroidism.* Both these types of abnormalities lead to the development of altered personalities in humans. This hormone is therefore called *personality hormone*.

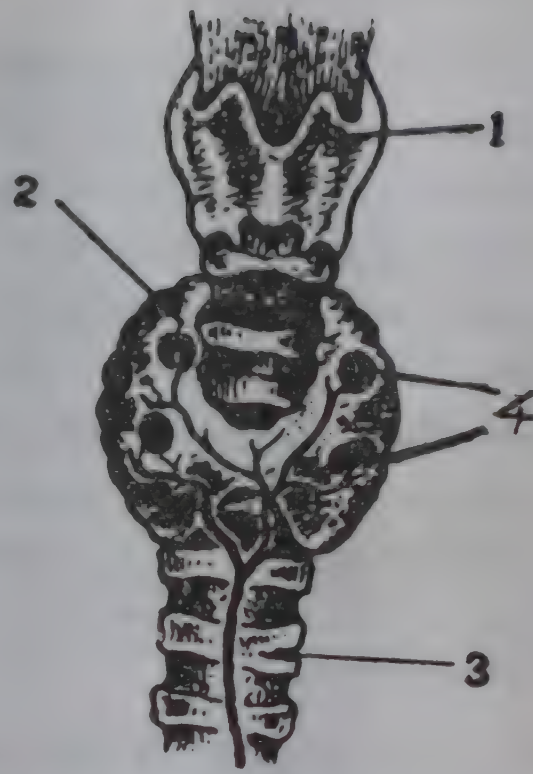


Fig. 5.3. The location of the Thyroid gland

1. Throat cartilage,
2. Thyroid gland
3. Trachea
4. Parathyroid.

Hypothyroidism

This is a condition in which the thyroid gland fails to produce enough thyroxin to meet the normal requirements of the body. The following are the three abnormalities caused by the under-secretion of the thyroid gland.

Simple Goitre

In case where the thyroid is not developed normally, it unduly enlarges producing a swelling in the neck known as *goitre*. Thyroid glands enlarge in order to meet the production of thyroxin for the normal functioning of the body. Goitre can be cured by administering iodine along with food and water. Goitre cases are mostly found in places where iodine is less in soil and water. Usually coastal people do not suffer from goitre because sea water and soil are rich in iodine.

Myxedema :

This condition is caused by an underactivity or degeneration of the thyroid gland in an adult. Underfunctioning of the gland causes under-development of the individual and it also results in low metabolic rate, loss of mental and physical vigour, increase in weight due to accumulation of fat, thickening of the skin, increased susceptibility to cold and lower rate of heart beat. When proper doses of thyroxin are given to such an individual the metabolic rate becomes normal again and the other symptoms disappear.

Cretinism :

A very low output of thyroxin in a new born child if left untreated leads to a disease called *cretinism*. In a human cretin, growth is stunted and mental development is greatly retarded. Other effects are bowlegs, defective teeth, enlargement and protrusion of the tongue and a coarse and leathery texture of the skin. These effects can be overcome or prevented if treatment is given in time.

Hyperthyroidism :

This is a condition that results from an over activity or an enlargement of the thyroid. In both cases thyroxin is produced in excess of the normal requirement. This results in the acceleration of the metabolic rate accompanied by an increase in heat production. Among the symptoms of this disorder are high blood pressure. nervous tension, irritability, profuse sweating, loss of weight and fatigue. Sometimes there may be a protrusion of the eyeballs. When this condition is severe, death usually results unless an individual is treated in time.

The Parathyroid Glands :

There are four very small parathyroid glands embeded in the tissues of the thyroid. The secretion of the parathyroids is known as *parathormone*. This hormone regulates the amount of calcium salts in the blood stream. Normal amounts of these salts are needed for the muscles to relax. A shortage leads to painful muscle cramps. Excess of parathormone robs bones of calcium, making them soft.

The Adrenal Glands :

The adrenal glands are a pair of small triangular cap-like bodies, each lying at the top of a kidney (Fig. 5.4). They are yellowish in colour and richly supplied with blood. These are also known as *suprarenal glands*. Each adrenal gland consists of an outer *cortex* and an inner *medulla*. The *adrenal cortex* secretes many hormones. These hormones regulate the rate of metabolism and the concentration of the salts in blood and protect the body when it experiences shock as in an accident. These are steroid hormones. One of these is known as *cortisone*. It is also made synthetically and is used in the treatmant of arthritis and certain skin diseases. Rest of the hormones secreted by adrenal cortex affect the rate at which kidneys do their work, influence the sex organs, and affect the balance of dissolved

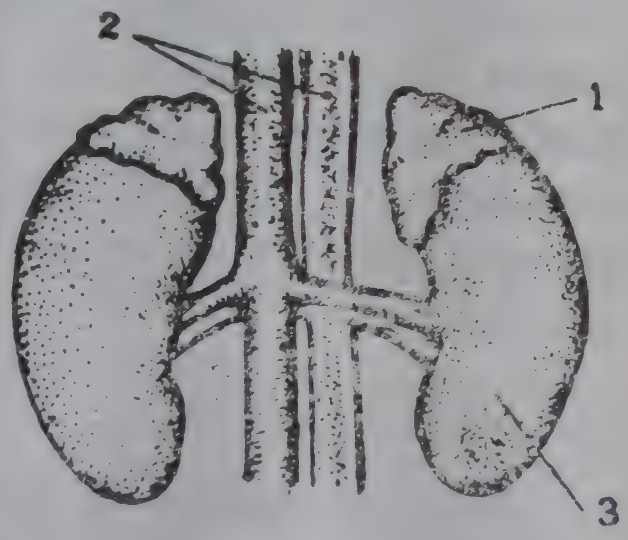


Fig. 5.4. The Location of the Adrenal Glands.
1. Adrenal Gland
2. Blood Vessels
3. Kidney.

salts in the blood. A failure of adrenal function causes some salts to become scarce and others too abundant. The result is loss of weight, drying out of the tissue, weakness and possible heart failure.

The *adrenal medulla* secretes two hormones namely *adrenaline* and *noradrenaline* of which adrenaline is the most important one. It is normally present in blood in small quantities. This hormone is secreted in excess at times of fear, anger, or other emotional stress and prepares the body to face an emergency. Since adrenaline brings about a coordination of several events to prepare the body to face an emergency, it is often refered to as the *emergency hormone.* Adrenaline is now made synthetically and it usually finds a place in the physician's kit, because of its many emergency uses. It is widely used in the treatment of asthma to dilate the bronchioles, to increase blood pressure and even to restore heart beat in a heart that has just stopped.

The Islets of Langerhans :

Pancreas consists of two sets of secretory cells. One set secretes pancreatic juice containing digestive enzymes, poured into the duodenum through the pancreatic duct. Another set of cells embedded in the pancreas is known as *islets of Langerhans* (Fig. 5.5). Among the islet cells there are two types of secretory cells, namely the *alpha cells* and the *beta cells.* The alpha cells produce a hormone called *glucagon* which converts glycogen into glucose and increases the synthesis and release of glucose into the blood. The beta cells produce another type of hormone known as *insulin.* Insulin controls the amount of glucose in the blood.

Fig. 5.5. The location of the Islets of Langerhans in the Pancreas
1. Stomach 2. Intestine 3. Pancreatic Duct
4. Pancreas 5. Islet Cells,

It plays an important role in the regulation of carbohydrate metabolism. It helps in the removal of excess glucose from the blood. Insulin helps in storage of glucose in the form of glycogen.

Deficiency of insulin causes the disease known as *diabetes mellitus* in which the liver fails to store sugar and the body cells cannot use it. This leads to the increase of sugar in the blood above the normal level. Excess blood sugar (glucose) is excreted in the urine. Frequent urination and thirst are two of the common symptoms of diabetes. This disease can be controlled by the administration of injections of insulin and by certain drugs. An untreated diabetic patient suffers from thirst, excessive urination, loss of weight and weakness. If the disease is severe it leads to coma ending in death.

The Gonads

Gonads are organs that have two functions. They produce sex hormones in addition to sperms or egg cells. The testes produce male hormones or *androgens*, of which the most common is *testosterone*. These hormones are responsible for the development of the characteristics which we term masculine. Thus during puberty or sexual maturity, a boy's voice cracks and then deepens. Beard appears and there is an increase in body hair. Hypofunction of this gland will produce under-sexed individuals whose masculine characters are developed to a low degree. Hormone treatment of such individuals may produce marked changes in their entire personality and enable them to become well adjusted members of the society.

The ovaries produce one group of hormones known as *estrogens* of which the most common is *estradiol*. They promote the development of feminine characteristics. Estrogens also play an important part in the reproductive cycle of a mature woman. It prepares the walls of the uterus for the possible reception of the fertilized egg. *Corpus luteum* an yellow body in the ovary secretes the hormone *progesterone*, which effects the final uterine changes necessary for gestation (pregnancy). Hyposecretion of estrogens may result in under-sexed women with infantile reproductive organs and consequent sterility.

Hormones secreted by Major Endocrine Glands and their effects

Endocrine Gland	Hormones formed	Functions
1. Pituitary Gland	Secretes several hormones.	1. Influence the rate of growth of the body. 2. Stimulate secretion of thyroxin. 3. Stimulate the activity of the adrenal glands. 4. Stimulate the secretion of milk from the mammary glands. 5. Stimulate the excretion of water from the kidneys. 6. Influence the development of the ovaries and the testes.
2. Thyroid Gland	Thyroxin	1. Speeds up the rate of metabolism of the body.
3. Parathyroid Gland	Parathormone	1. Regulates the amount of calcium salts in the blood stream.
4. Adrenal Gland	Many hormones	1. Regulate the rate of metabolism and the concentration of salts in the blood.
(a) Adrenal Cortex		2. Protects the body when it experiences the shock of an accident. 3. Influence the sex organs. 4. Affect the rate at which the kidneys do their work.

Endocrine Gland	Hormones formed	Functions
		5. Useful for treatment for arthritis and some skin diseases.
(b) Adrenal Medulla	1. Adrenaline 2. Noradrenaline.	1. Prepares the body to face an emergency.
5. Islets of Langerhans		
(a) Alpha cells	Glucagon	1. Converts glycogen into glucose and helps synthesis of glucose in the blood.
(b) Beta cells	Insulin	2. Helps in storage of glucose in the from of glycogen; controls the amount of glucose in the blood.
6. Gonads		
(a) Testes	Androgens	1. Promote the development of masculine characteristics, Sperm production.
(b) Ovary	Estrogens.	1. Promote the development of feminine characteristics; egg development and ovulation; maintenance of pregnancy.

At Home

To demonstrate the effect of thyroxin on the metamorphosis of frog.

Take two lots of tadpoles which are just beginning to show development of their hind limbs. Put them in separate jars of water. Each jar should contain water weeds in order to aerate the water. Crush two 30 mg. thyroxin

tablets and spread the powder on small bits of raw meat Sprinkle the treated meat on the surface of water of one jar. Sprinkle the other jar with untreated meat. After about a week tadpoles in the first jar will have developed fore-limbs, and their tails will have grown smaller, while the tadpoles in the second (untreated) jar will not have altered.

Questions

I. 1. Name any two endocrine glands in the human body. Where are they situated? What hormone do they secrete?

2. What is acromegaly? How is it caused?

3. Name the three abnormalities of hypothyroidism.

4. How is diabetes mellitus caused? What are its symptoms?

II. *Give reasons for the following*:

1. Hormones are called chemical messengers.

2. People living near sea shores do not get goitre.

3. Adrenaline is called 'emergency hormone'.

4. Diabetic patients should use less rice and sugar. – To avoid excessive loss of weight

III. *Name the following*:

1. Hormone secreted by the adrenal cortex. cortisone

2. A hormone secreted by the testis. Testosterone

3. A hormone secreted by corpus luteum. Progesterone

4. Another name for adrenal gland. Suprarenal gla...

IV. *Fill in the blanks*:

1. Parathyroid glands are embeded in ——— thyroid g...

2. estradiol is the common estrogen produced by the ovaries.

3. Thyroxin is called personality hormone.

4. Hormone produced by the alpha cells of islets of Langerhans is ———. glucagon

* * * *

CHAPTER 6

Heredity

You may have heard people remark—‘ her eyes are just like her mother’s ‘ his grand father had such a sharp nose’, and so on. You are not surprised if anyone resembles his or her parents, but you may wonder how features of grand-parents appear in grandchildren without being present in the parents. From a very long time many have wondered why inheritance of characters is often discontinuous. How does a feature appear in a later generation after skipping one or more generations ? How and where is it ‘hidden’ in the intervening generations ? Not until the last century answers to these questions were obtained. In the past few decades we have begun to understand the chemistry of inheritance.

Genetics is the branch of biology which explains how *heredity* and *variation* take place. Heredity is the transmission of *characters* or features from parents to offspring. It deals with the factors responsible for the resemblance between parents and their children. *Variation*, is the difference between related individuals. It’s study lets us know what variations are hereditary and what variations are due to the environment.

Before studying heredity recollect the facts you have learnt about types of cell division, chromosomes, genes DNA, sexual and asexual reproduction in your earlier, classes.

During *mitosis*, daughter cells are produced which have same number and types of chromosomes as the parent cell. The daughter cells have the same *genes*, linearly arranged on the chromosomes. The genes are portions of DNA in the chromosomes.

Each gene has information for a specific feature or function. Asexually reproduced organisms have the same genes as the parent individual because they arise only by *mitotic cell divisions*. The variation between asexually reproduced individuals is mainly due to the effects of the environment.

You know that sexual reproduction involves the fusion of two gametes. The gametes are haploid and arise by the process of cell division called *meiosis* or reduction division. Meiosis and sexual reproduction can bring about variation in individuals in the following manner. Observe Fig. 6.1. It shows two gametes, egg and sperm with 3 chromosomes each (n=3). The chromosomes are marked different to indicate differences in their genetic makeup. They fuse to form a zygote which gives rise to an individual with a diploid number of six chromosmes (2n=6). When such a diploid individual produces gametes by meiosis, eight different chromosome combinations are possible ($2^n=2^3=8$). Similarly in a human being with 23 pairs of chromosomes, the possible number of chromosome combinations at gamete formation are 2^{23} *i.e.*, 8,388,608. This shows why meiosis and the sexual method of reproduction produces so much

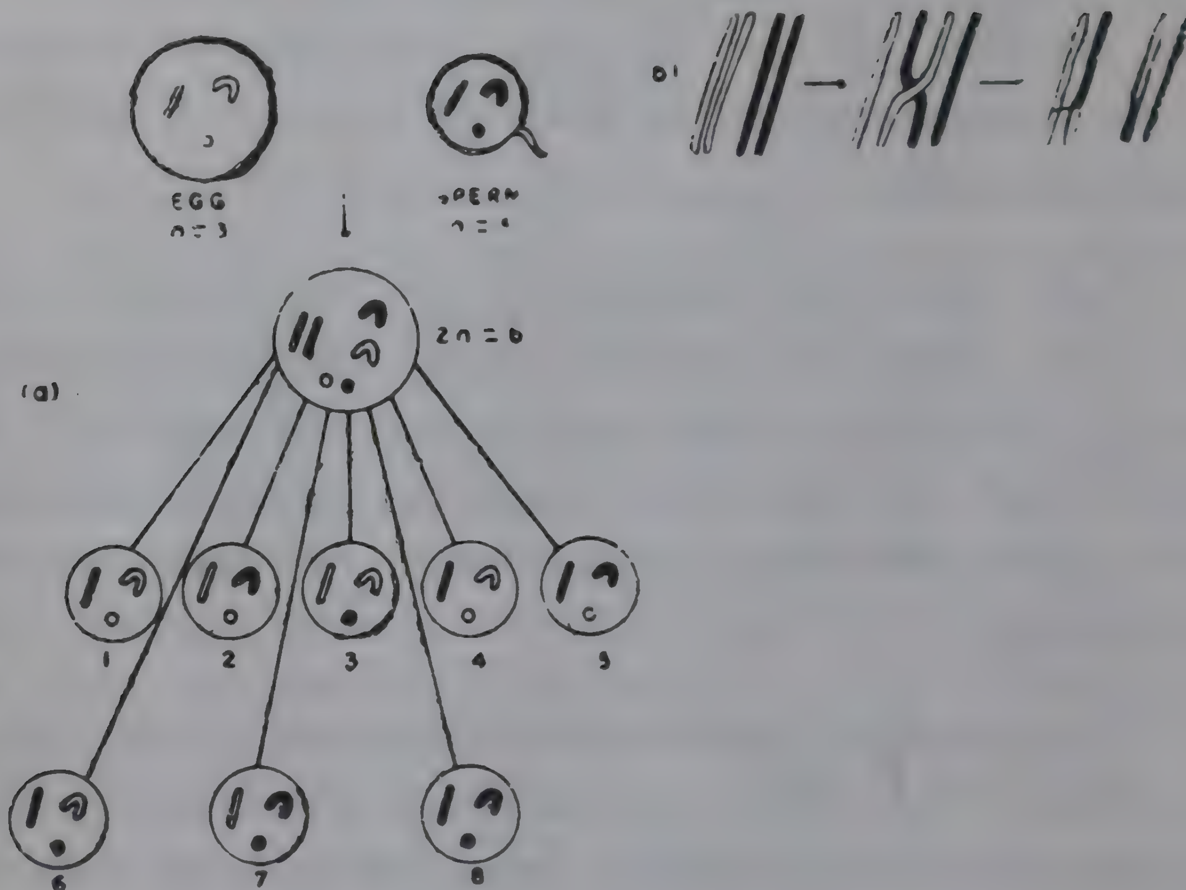


Fig. 6.1. How variation is produced during meiosis

(a) Eight possible combinations of chromosomes during meiosis when n=3.

(b) Chromatids crossing-over during pairing of homologous chromosomes.

variation. It also explains why children do not exactly resemble their parents. Indeed many more combinations of genes in chromosomes occur during meiosis when paired homologous chromosome exchange parts of their chromatids by *crossing over*.

Mendel's Experiments

In order to understand heredity, let us study Mendel's experiments with garden pea (*Pisum sativum*). Gregor

Mendel, an Austrian monk, (Fig. 6.2) conducted *crossing* or *hybridization* experiments during 1856–1863. However the significance of his work was not recognized till 1900, when three other scientists did similar experiments independently and came to the same conclusion.

Fig. 6.2 Gregor Mendel

Mendel selected for his work the garden pea because these plants are normally self-pollinating (self fertilizing) plants. However they can be readily cross pollinated. Mendel realized that inheritance can be best understood if *contrasting forms of a single character are studied one at a time*, for example, the *tall* and *dwarf forms* of single character namely height of the plant, the *red* and *white forms* of flower colour, the *round* and *wrinkled forms* of seed shape or appearance and so on. He then obtained *pure* or true *breeding* varieties of each of the contrasting forms by self-pollinating the plants for several generations. By this, he got *tall* pea plants whose seeds always produced tall offsprings, *dwarf* plants whose seeds always produced dwarf offsprings and so on.

Monohybrid Ratio

Mendel then crossed (that is cross pollinated) a tall with a dwarf plant. These form the parental generation (P). To prevent self-pollination, he removed the anthers of flowers which were to serve as the female parent before the flowers opened and anthers shed pollen. After pollination, these flowers were covered in a bag to prevent any

other pollen falling on them. Thus the pollen of dwarf plant was used to pollinate the pistil of the tall plant, or the pollen tall plant to pollinate the pistil of the dwarf plant. He collected the seeds of these cross pollinated plants and sowed them in the next season. He expected the hybrid or crossed plants to be intermediate in height. But to his great surprise he found all the plants were *tall*. He called these hybrids the F_1 or *first filial generation* (Fig. 6.3). He obtained the seeds of the F_1 generation of plants *following self pollination*.

In the next season he planted the seeds of F_1 generation and obtained the second *filial generation* or F_2 plants. The F_2 plants were a mixture of tall and dwarf plants. In one experiment he found, out of the total of 1064 plants, 787 were tall and 277 dwarf. Thus the ratio of tall to dwarf plants was approximately 3 : 1 in the F_2 generation.

Mendel repeated the above experiments with other contrasting forms of characters some of which are shown below and always obtained a ratio of about 3:1 in the F_2 generation. This ratio is called the *monohybrid ratio* since contrasting forms of only one character was crossed or hybridized.

Parent (P)	F_1	F_2	Ratio
Yellow × green seed	All yellow	6022 yellow:2001 green	3.01:1
Red × white flowers	All red	705 red:224 white	3.15:1
Round × wrinkled seed	All round	5474 round:1850 wrinkled	2.96:1

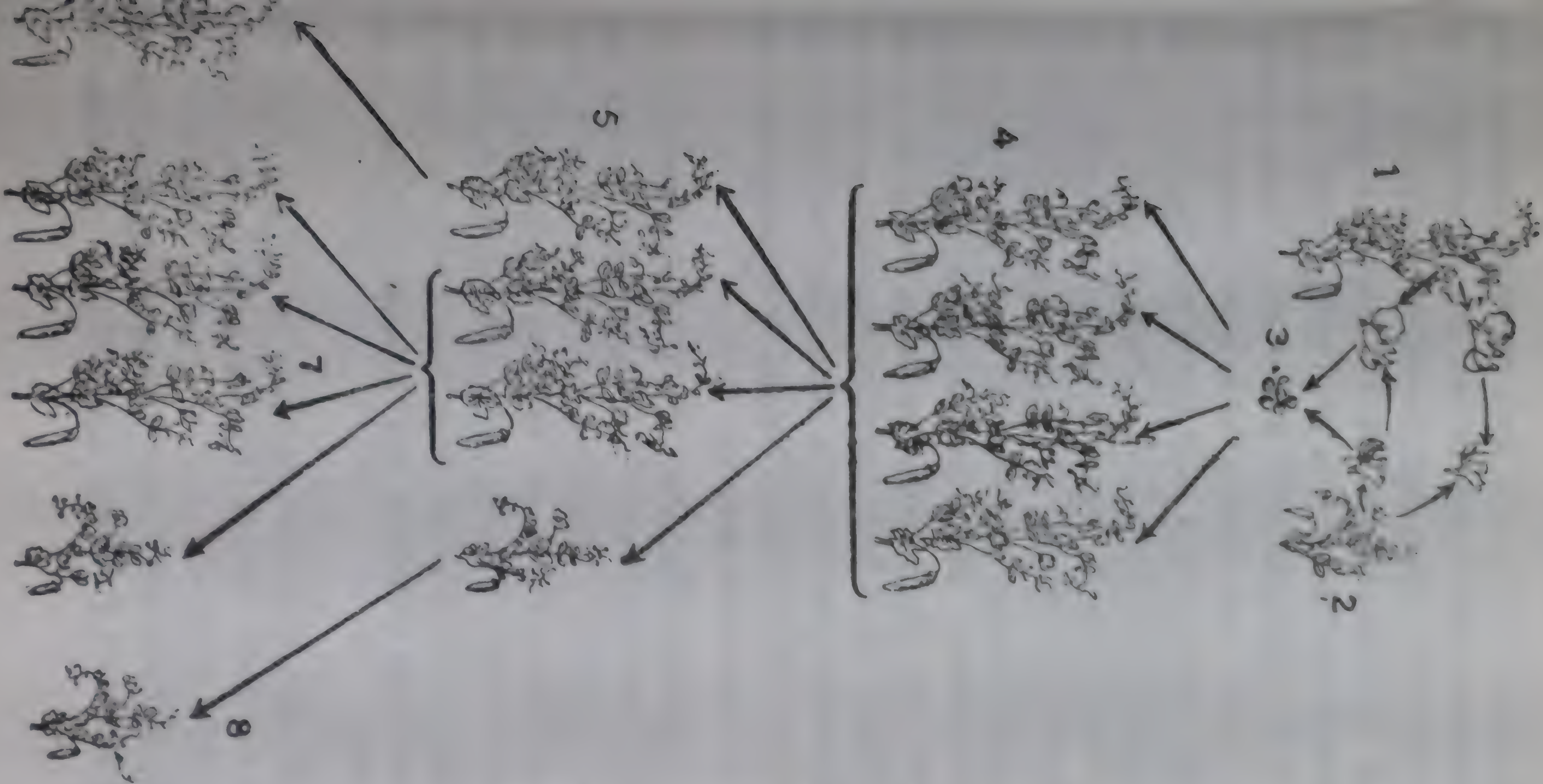


Fig. 6.3 Illustration of Mendel's experiments

1. Tall parent (P) 2. Dwarf parent (P) 3. Seeds Produced by the cross pollination of (1) and (2) 4. Hybrid plants of the I generation (F_1) 5. Plants of the II generation (F_2). Note the 3:1 ratio of tall: dwarf. 6. The 'pure' tall plants of the II generation produced only tall plants in the III generation (F_3) 7. The 'impure' tall plants (namely half the number of generation) produced tall and dwarf plants in 3:1 ratio in III generation 8. The dwarf plant ('pure') of the II generation produced only dwarf plants in the III generation.

Mendel then set out to find an explanation for the constant 3:1 ratio in the F_2 generation. He argued that each contrasting form of a character should be controlled by a *factor*. That is, there should be a factor for *tallness*, a factor for *dwarfness*, a factor for producing yellow seed, a factor for producing green seed and so on. In the experiment where the tall and dwarf plants were crossed, the F_1 plants, though all tall, must have contained the factors for both *tallness* and *dwarfness*. This is because when F_1 plants were self pollinated, the F_2 generation produced some dwarf plants along with tall plants. The factor for dwarfness however remained hidden or concealed in F_1 in the presence of the factor for tallness. Mendel called the factor for tallness *dominant* over the factor for dwarfness which he called *recessive*. The F_1 plant had therefore inherited a factor for tallness from its tall parent and a factor for dwarfness from its dwarf parent. These factors should have come from the pollen and the egg which gave rise to it.

Mendel concluded that since the F_1 plant contained two factors for any one character, every individual should also contain two factors for a character, one from each parent. The factors may be of the same type or contrasting types. For example it may be both for tallness, both for dwarfness, or one for tallness and one for dwarfness. *Only one factor of a pair of contrasting character was however present in the egg or the pollen.*

Let us call the factor for tallness as *T* and that for dwarfness as *t*. Then the pure-breeding tall parent has two *T*'s, that is *TT*, having inherited a *T* each from its own pure-breeding tall parents. The pure-breeding dwarf parent is *tt*, having inherited a *t* from each of it's pure-breeding

dwarf parents. The tall parent *TT* produces all eggs or pollen with a *T* each, while the dwarf produces all eggs or pollen with a *t* each. The F_1 hybrid is formed by a fusion of a gamete with *T* from tall parent and a gamete with *t* from dwarf parent and it is therefore *Tt*. But since *T* is dominant over *t*, the F_1 hybrid is tall. But it is an *impure* tall since it contains a *t* also.

When F_1 is selfed (self fertilized), it produces two types of egg cells *T* and *t*, and two types of pollen *T* and *t*. They can fuse to form three types of zygotes *TT*, *Tt* or *tt*. Starting with equal numbers of *T* and *t*, *for every four zygotes formed*, one will be *TT*, two will be *Tt* and one will be *tt*, as shown below.

		Pollen of F_1 T	t
Egg cells	T	TT	Tt
of F_1	t	Tt	tt

In appearance, there will be three tall plants (one TT and two Tt) for every dwarf (tt) plant, hence the ratio of 3 tall : 1 dwarf. Notice that only one out of every three tall is *pure* or *homozygous* for tallness *i.e. TT*. When selfed it will produce only tall plants and so is called true breeding and it is like one of the parents. The other two tall plants (Tt) are *impure* or *heterozygous* and will not breed true. When selfed their offsprings will be both tall and dwarf in the ratio of 3:1. The dwarf (tt) is homozygous and always true breeding; when selfed its progenies are all dwarfs.

Dihybrid Ratio

Mendel also crossed plants (parental forms) with two pairs of contrasting characters, such as a *tall plant with*

red flowers with a *dwarf plant with white flowers.* The factor for producing red flower is dominant over the factor producing white flower, just as factor for tallness is dominant over dwarfness. In the F_1 generation all the plants were *tall and had red flowers.* When F_1 was selfed, four types of F_2 plants were produced as follows ·

(a) Tall and red flowered	One parental form
(b) Tall and white flowered	Intermediate forms
(c) Dwarf and red flowered	
(d) Dwarf and white flowered	Other parental form.

The intermediate forms (b) and (c) indicate that the factors for the different characters (height of plant and colour of flower) could *move* or *assort* independent of each other. The four types (a), (b), (c) and (d) occured in the ratio of 9:3:3:1. By preparing a *checker board*, you can see how this is obtained.

Let *T* and *t* represent factors for tallness and dwarfness and let *R* and *r* represent factors for red and white flowers colour.

The parents (P) are TTRR and ttrr and they produce only one type of gamete TR or tr. The F_1 is therefore TtRr. The F_1 can produce four types or pollen and four types of egg cells. TR, Tr, tR, and tr.

Female gametes

		TR	Tr	tR	tr
	TR	TTRR	TTRr	TtRR	TtRr
	Tr	TTRr	TTrr	TtRr	Ttrr
Male	tR	TtRR	TtRr	ttRR	ttRr
gametes	tr	TtRr	Ttrr	ttRr	ttrr

The following information is summarised from the *checker-board.*

TTRR	—	1	
TTRr	—	2	.... 9 Tall red flowered
TtRR	—	2	
TtRr	—	4	
TTrr	—	1	.... 3 Tall, white flowered
Ttrr	—	2	
ttRR	—	1	.... 3 dwarf, red flowered
ttRr	—	2	
ttrr	—	1	.... 1 Dwarf, white flowered

Mendel's findings may be summarised as *three laws of heredity.*

1. *Law of dominance* : When two factors responsible for the contrasting forms of a character are present together, normally one expresses itself, while the other remains concealed.

2. *Law of segregation :* The factors for contrasting forms of a character separate out during gamete formation. A gamete contains *only one factor* of a contrasting pair. (Hence this is also known as the *purity of gametes*).

3. *Law of independent assortment* : Factors controlling separate characters normally move independent of each other during gamete formation. So combinations of characters which are not present in the parental forms are produced in the offspring.

Mendel's discoveries of laws of inheritance were followed by the discovery of chromosomes in cells and of the processes of cell division by *mitosis* and *meiosis*. It was subsequently shown that the factors of Mendel were located on the chromosomes as *genes*. You may recall that the diploid cell has chromosomes in pairs called *homologous* pairs. Each gene on a chromosome is therefore represented twice in a diploid cell. In a homozygous individual both the genes for a character are identical. In a heterozygous individual the two genes represent two contrasting forms of a character. For example, you have a gene for tallness and a gene for dwarfness. These two genes are called *alleles* since they occupy the same position on the two homologous chromosomes.

You now know how the *genes* or *factors* controlling charactors may not be expressed in every generation. The genes for *dwarfness* and *white flowers*, though present in the F_1 generation were not expressed. They showed up in a later generation. Even in the F_2 generation, though these genes were expressed in only a few individuals, all the *impure heterozygous* forms have them, to be expressed in future generations.

Mutations

The environmental variations are not inherited by the offspring. But changes in the hereditary material, on the other hand, are heritable. Such changes are known as *mutations*. There are two types of mutations namely, *gene mutations* and *chromosome mutations*. Gene mutations result from a change in the chemical structure of a gene. Biochemically a change in the gene is alteration of

nucleotide sequence in a specific region of a DNA molecule. Chromosome mutations may result from either changes in the structure or number of chromosomes.

Mutations may occur in somatic cells or gametes and only those mutations that appear in gametes are transmitted from one generation to the other. New forms may arise by a single mutation. T. H. Morgan (1910) was the first to notice gene mutation in the fruitfly (*Drosophila melanogaster*). Due to mutations we find a number of varieties in the fruitfly. Gene mutations occur under natural conditions at a very low frequency. Such natural or spontaneous mutations have been shown in the case of maize (*Zea mays*) to occur in the frequency of 1 in 100,000 to 1 in 1, 000,000 per generation. Spontaneous mutation occur in both plants and animals. The rate of mutations may be artificially increased by certain agents called *mutagens*. Chief among mutagenic agents are X–ray and ultraviolet radiation and certain chemicals such as nitrous acid.

Chromosome Mutations

In addition to gene mutations there are mutations which involve the entire chromosome. Some modify the number of chromosomes while others alter the genetic structure of the chromosome (*deletions*, *translocations* and *inversions*). Numerical increase of chromosome result in *polyploidy*. Polyploidy is common in plants but rare in animals. Typically, flowering plants have two haploid sets of chromosomes and are said to be diploid(2n). However, some plants contain more than two haploid sets of chromosomes, and these are referred to as polyploids *viz.*—triploids (3n), tetraploids (4n), pentaploids (5n), so on. Of these polyploid

conditions, tetraploids are most common in nature. Hugo de Vries noticed a tetraploid for the first time in evening primrose (*Oenothera lamarckiana*). Polyploids may occur naturally because of a failure of a cell to undergo meiosis followed by gametic fusion or because of a division of the nucleus without subsequent cytoplasmic separation or *cytokinesis*. Tetraploids, especially, can be made to occur with greater frequency if plants are treated with a poisonous drug called *colchicine*.

Sex-linked Inheritance

The sex of a person can have an effect on the pattern of gene expression. The difference in the sex-chromosomes is one important factor. A distinctive pattern of inheritance results from the genes of X chromosome. These are known as X-linked or sex-linked genes and the inheritance is known as sex-linked inheritance.

Sex-linked gene cannot be transferred directly from father to son, but goes from mother to her sons. A daughter can receive the sex-linked gene directly from any parent. The best known sex-linked traits in man are *colour blindness* and *haemophilia*. In man the genes that determine red-green colour blindness and hemophilia are linked to sex chromosomes.

Colour Blindness (*Daltonism*)

It is a condition of faulty colour vision. A man with this gene which is recessive on his single X chromosome will be red-green colour blind. He cannot transmit this trait to his sons, since they get their X chromosomes from the mother, but his daughters can receive the gene from him.

However they most likely will receive the normal dominant allele from the mother. Therefore they will not be colour blind. Thus grandsons of the colour blind man, through his daughters may also be colour blind. A colour blind girl can

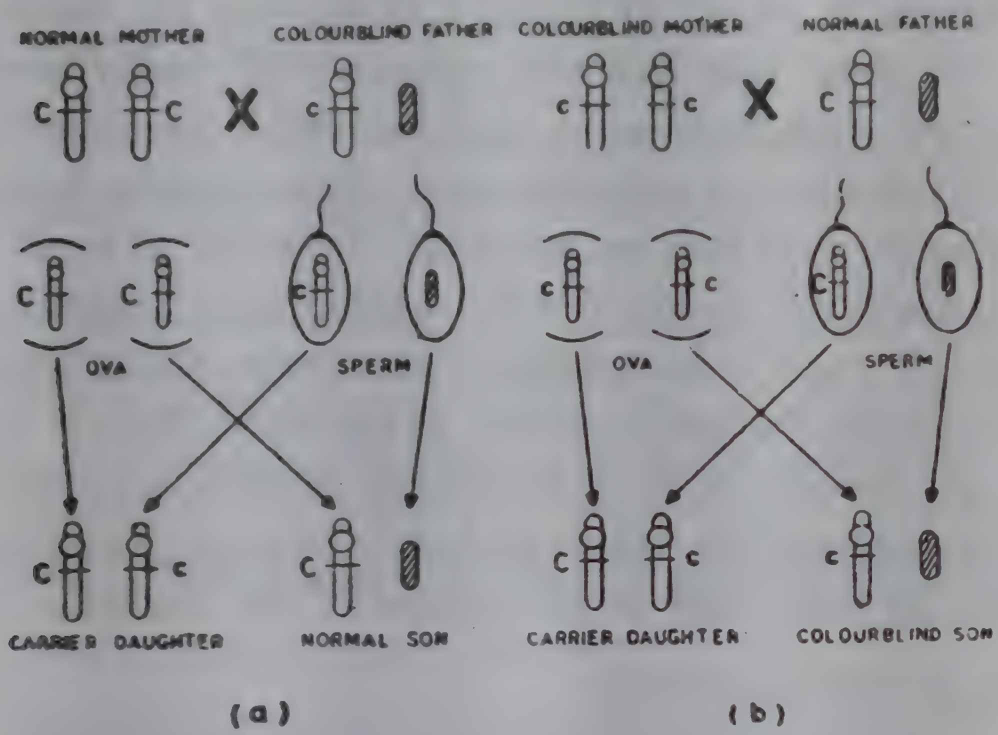


Fig. 6.4 Sex linked inheritance of colour blindness

C — dominant gene for 'normal' eye

c — recessive gene for 'colour blind' eye

CC — normal eye

Cc — normal eye ;
carrier of colour blindness

cc — colour blind eye

be produced only if the father is colour blind and the mother is a carrier or is colourblind. Hence, there are many more colour blind men than women. About 8 per cent of males have daltonism whereas this is found only in 0.5 per cent of females.

Haemophilia (Bleeder's disease)

It follows the same mode of inheritance as colour blindness and is due to a recessive sex-linked gene. Haemophilia is a condition in which the blood fails to clot after a surface or internal injury or else clots very slowly. Normal blood takes about 5 minutes to clot but in haemophilic individuals it may take upto 120 minutes for the blood to clot. A man who has this disease will suffer prolonged bleeding from light injuries and may bleed to death if something is not done to stop bleeding. Haemophilia is far more common in men than in women. However in areas where cousin marriages occur, female haemophilic individuals are found. If a girl is haemophilic, the father must be haemophilic and the mother a carrier of haemophilia. A haemophilic girl usually dies on reaching maturity. More than half the haemophilic males die before becoming adults; some of them do not marry at all because of the disease.

Dominant Sex-linked gene

The sex-linked genes for colour blindness and haemophilia are due to recessive genes in the X chromosome and are therefore more common in men than in women. But few sex-linked genes are dominant and more common in women; for example, the gene causing defective enamel of the teeth. Teeth of persons having this gene wear down quickly. Since women have two X chromosomes they have greater chance of receiving this gene than men who have only one X chromosome.

Questions

1. What is heredity ?
2. What is variation ? What are its causes ?

3. Describe Mendel's experiment with tall and dwarf pea plants.

4. State Mendel's three laws of heredity ?

5. What is gene mutation ? How does it differ from chromosome mutation ?

6. What are polyploids ?

7. What is sex linked inheritance ? Give examples.

8. Draw a checker board to show the dihybrid ratio.

II Give reasons :

1. Usually children resemble parents. Heredity

2. The genes for tallness and dwarfness are called alleles.

3. The environmental variations are not inherited by the offspring.

4. In some plants polyploidy is common.

5. Sex-linked gene cannot be transferred directly from a father to his son. The Son gets X chromosome from his m

6. A haemophilic girl normally dies upon reaching maturity.

because blood takes 120 minutes to .... clot.

CHAPTER 7

Reproduction in Man

You have studied that life is perpetuated from one generation to the next by reproduction. It is a process by which every kind of organism produces new individuals of its own kind. As in all higher animals, humans reproduce only by the sexual process. Sperm cells or male gametes produced by the male are deposited in the reproductive tract of the female. Here *internal fertilization* takes place with the formation of the *zygote*. The zygote develops to the stage of a baby in the body of the mother in about nine months when it can carry on life processes on its own. It is then delivered and becomes a separate individual.

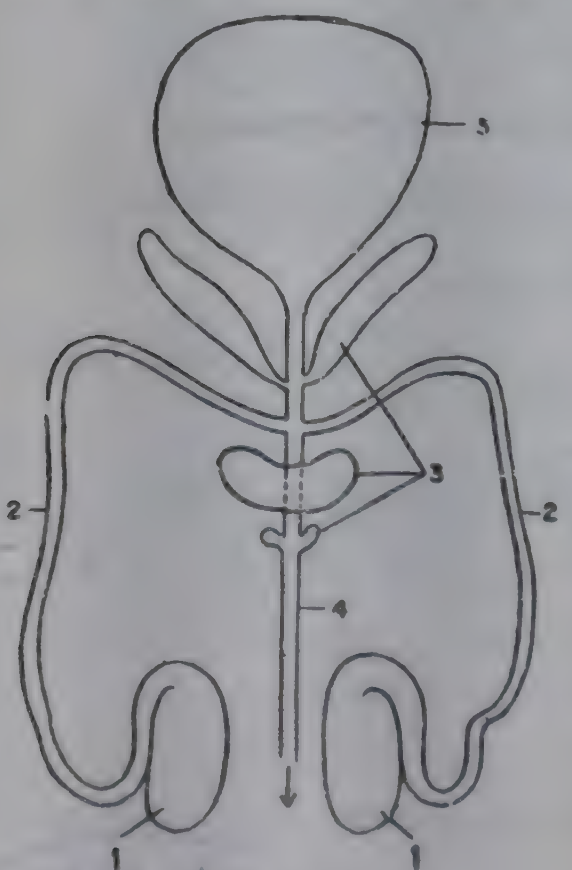


Fig. 7.1 A
Male Reproductive System.
1. Testes 2. Sperm duct
3. Accessory glands 4. Urethra
5. Urinary bladder

Male reproductive system

A pair of male reproductive organs or *testes* produce *sperm cells* or *sperm*. The sperm cells are small and do not have stored food in them. A pair of *sperm ducts* carry the sperm to the *urethra* and hence to the outside. On the way sperm is combined with the secretions of accessory organs which provide them with a source of nourishment. The secretions called *semen* is

a whitish fluid. Over a hundred million sperm cells are normally present in a millilitre of semen when discharged.

Female reproductive system

This consists of a pair of ovaries which produce egg cells or ova. A pair of tubes or *oviducts* serve to carry the egg when liberated by the ovary, to the *uterus* or *womb.*

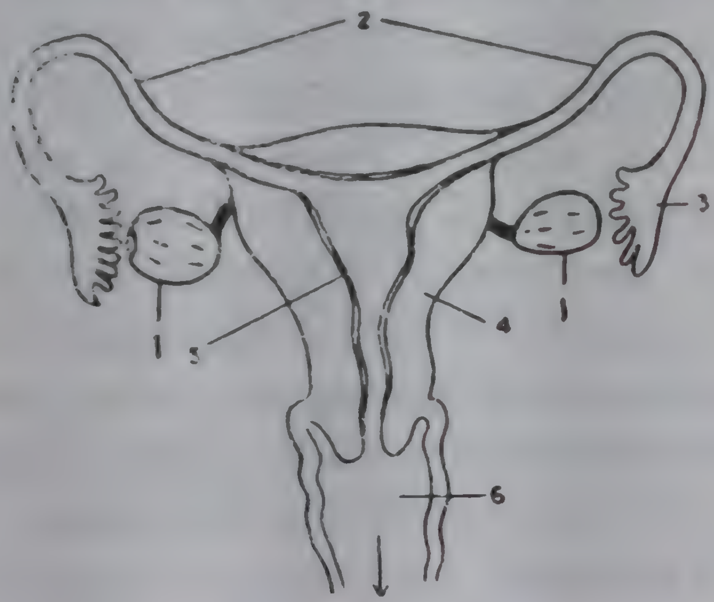


Fig. 7.1 B Female Reproductive System

1. Ovaries
2. Oviducts
3. Funnel-shaped end of oviduct
4. Uterus
5. Uterus lining
6. Birth canal (Vagina)

The oviduct (also called *fallopian tube*) has a funnel-shaped end near the ovary through which the egg enters. The uterus is a thick walled, three-cornered structure. The two oviducts lead in to it at two corners, while the third corner leads to the outside through the *birth canal* or *vagina.*

Sexual maturity in human beings

As in all higher organisms, there is a period of growth and development of human individuals before he or she becomes capable of reproduction. The age of sexual

maturity (or puberty) in males is normally about 14–15 years and about 12–14 years in females. At this time hormones produced by the hypothalamus in the brain activate the anterior pituitary glands, to produce certain pituitary hormones. These in turn start sperm and sex hormone (testosterone) production in the testes in males and the formation of egg and female sex hormones production in the ovaries in females. With the onset of sex hormone production at sexual maturity, several bodily changes take place. These changes take place over a period of time when the young become adults. These are the *adolescent* years Some of these changes are growth of hair on parts of the face and chest, development of a larger and stronger body and the development of a richer and deeper voice in boys. In girls, a widening of the hip or pelvis region and a development of breasts take place. These changes help in future child birth and in feeding the young. Their voice. becomes more feminine.

Sexual maturity in females starts the production and release of eggs from the ovaries. Normally one egg is released about every 28 days from either one of the ovaries. It travels down the oviduct towards the uterus. If it is not fertilized within one or two days after its release, it dies. In anticipation of receiving the fertilized egg, the internal wall of the uterus starts developing a lining of tissue about 10-12 days *prior* to the release of the egg. In the absence of fertilization, this uterine lining disintegrates and is discharged (taking 2-3 days time) about two weeks *after* ovulation. (release of egg)The next cycle of forming the uterine lining then starts. This cycle, of about 28 days duration is called the *menstrual cycle*. Ovulation takes place at about the middle period of a menstrual cycle.

Fertilization and development of the embryo

If the egg cell comes in contact with sperm within a day on two of ovulation, fertilization takes place. Although only one sperm is involved in fertilization, numerous sperm cells present help in dissolving the materials sticking to the surface of the egg cell. This is effected by the hydrolytic enzymes present in the *acrosome*, a small body found on the head of sperm cells. The action of several sperm cells thus aid one sperm to penetrate the egg. Following the penetration of a sperm, a *fertilization membrane* quickly develops round the egg which prevents other sperms from entering. Fertilization normally takes place in the oviduct as the egg travels down to the uterus.

In human beings the fertilized egg reaches the uterus in 2-3 days by which time it has undergone several cell divisions. This ball of cells then attaches itself at some point of the uterine lining which has already been prepared for it. This process of attachment is called *implantation*.

During the next few days, a mass of special tissue called the *placenta* is formed around the embryo. The placenta provides a constant supply of food and oxygen to the developing embryo. It also helps in the elimination of waste materials from the embryo. Soon the embryo floats free in a fluid-filled membranous sac within the uterus and attached by a cord called *umbilical cord*, to the placenta. Through this cord the embryo is nourished with oxygen and food derived from the blood of the mother.

Two months after fertilization, the embryo attains a human shape. From this stage onwards it is called *foetus*. The period of *gestation* (pregnancy) is about nine months or

280 days in human beings. During this period, the fertilized egg, which is microscopic in size, is transformed into a tiny baby.

Towards the end of gestation period, the head of the foetus is turned down, towards the opening of the uterus, leading to the *birth canal* or vagina. The movements of the arms and legs of the foetus also become more frequent. The process of birth begins with the gentle contractions and relaxations of the muscle layers of the uterine wall. The

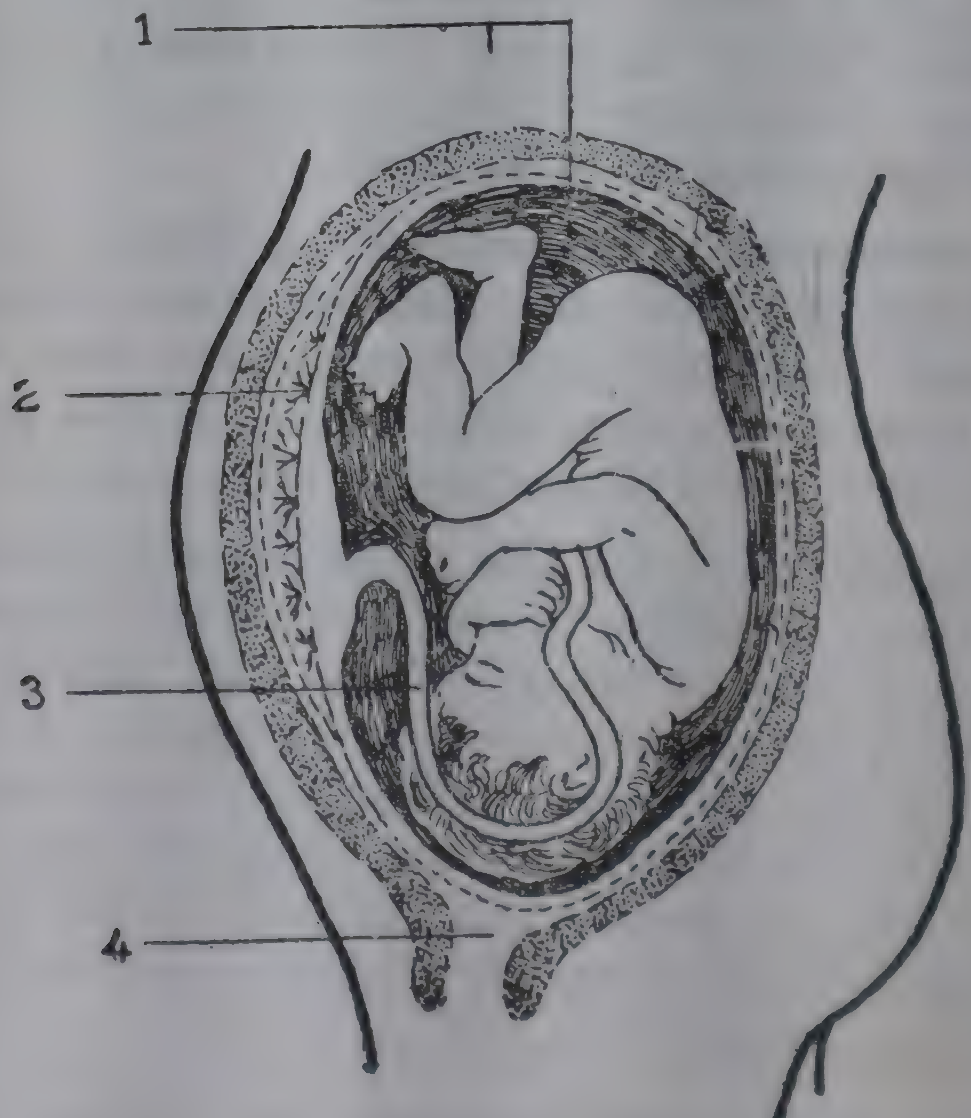


Fig. 7.2. A human baby ready to be born

1 Fluid surrounding the Baby 3. Umbilical cord

2. Placenta 4. Birth canal

foetus passes through the neck of the uterus, through the birth canal and then out of the body of the mother (Fig. 7.2). The new born child in still attached to the placenta by the umbilical cord. This cord in now tied and cut. The organic connection between the mother and the child thus ends. Rapid functional changes in the circulatory and respiratory systems of the new born infant occur immediately after birth.

During the period of *gestation*, the ovary does not release any eggs. That is ovulation is stopped. Ovulation and the menstrual cycle starts usually a few months after the birth of a baby.

Boy, Girl or Twins

In human beings there are 23 pairs of chromosomes. Out of these, one pair of chromosome is called *sex chromosome* because they determine sex. The remaining 22 pairs are called *autosomes.*

In man one sex chromosome is long and the other is short. The long chromosome is called the 'X' chromosome, the short one is called the 'Y' chromosome. In woman both the sex chromosomes are long and are called X chromosomes. The body cells in man therefore contain 44 autosomes and X and Y chromosomes whereas the body cells in woman contain 44 autosomes and two X chromosomes. During the formation of sperm and egg cells, meiosis (reduction division) takes place. Therefore each egg cell or sperm contains only half the diploid number of chromosomes that is 23. Out of these 22 are autosomes and only one is sex chromosome, *either X or* Y.

Man is *heterogametic* and produces two types of gametes. Half the number of sperms carry X chromosomes and the other half have Y chromosome. A woman is homogametic and produces only one type of gamete. They all carry X chromosomes. The sex of the child depends upon the kind of sperm that fertilizes the egg cell as shown in Fig. 7.3.

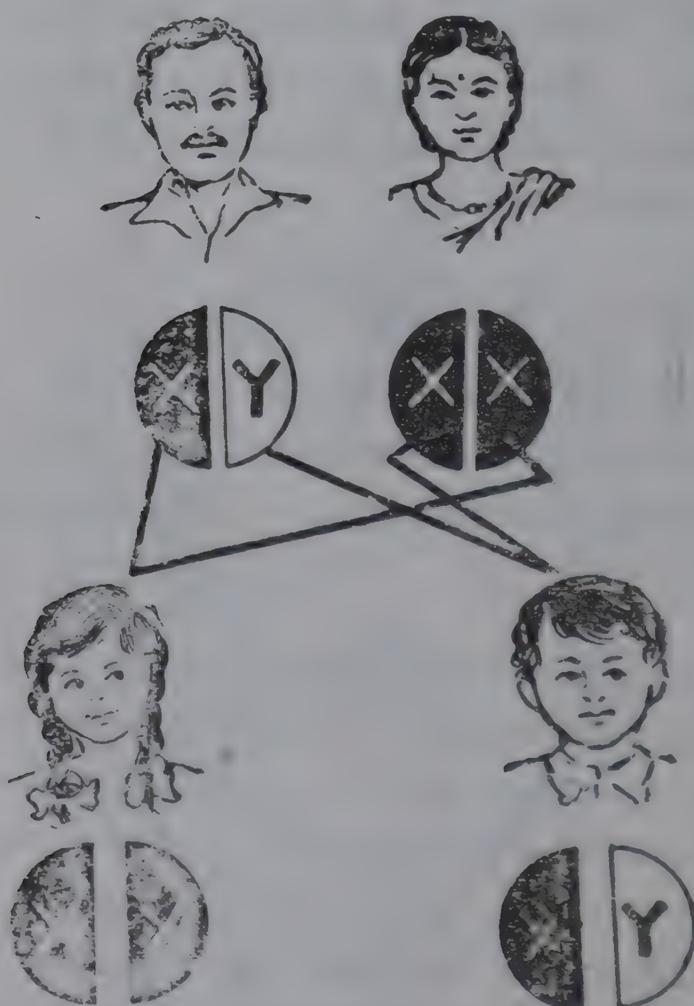


Fig. 7.3. Boy or girl.

If a sperm carrying the Y chromosome fuses with the egg cell the resulting zygote develops into a boy. If a sperm carrying the X chromosome fuses with the egg cell, the resulting zygote will develop into a girl.

Have you ever thought how twins are born ? The ovaries of a woman contain about 100,000 cells which can develop into eggs. Of these only about 400 ripen into eggs in her lifetime. Normally a single egg matures every month and if it gets fertilized, a baby is born. Sometimes, it so happens that two eggs mature together and on both being fertilized develop into twins. Such babies are called *fraternal or dizygotic twins.* They may be of same or different sex and may or may not resemble each other.

In contrast to fraternal twins, *identical* or *monozygotic twins* are so exactly similar to each other that it becomes difficult to identify them apart. They are always of the same sex and show a remarkable similarity in their appearance, behaviour as well as abilities. Identical twins arise from a single zygote. The first division of the zygote results in the formation of two similar cells. If these two cells happen to separate, two embryos will develop. Since the two embryos develop from a single zygote, they have the same genetic constitution. Very rarely three to five babies are born of a mother at the same time. They may be fraternal, identical or both.

Sometimes the separation of the cell is incomplete. The twins are born attached to each other and remain so even after. Such twins are called *Siamese twins* because the first well known twins of this type was born in Siam (Thailand).

Questions

1. What is reproduction ?
2. Which are the male reproductive organs of man ?
3. What is the age of sexual maturity in (1) males (2) females ?

4. What is placenta ? Mention its functions.
5. What is menstrual cycle ?
6. What are fraternal twins ? How are they formed ?

II. *Fill in the blanks :*

1. After fertilization, the egg is called baby ——.
2. Sperms are produced in —— Man
3. uterus —— is a thick walled three cornered structure.
4. oviducts —— ducts carry egg to the uterus.
5. At the time of sexual maturity hormones secreted by the —— in the brain activates the anterior pituitary gland.
6. There are 23 pairs of chromosomes in human cell.
7. XY —— chromosomes are present in the gametes.
8. A woman is —— and produces only one type of gamete.

III. *Name the following :*

1. The female reproductive organ. ovaries
2. The part of the sperm which contains hydrolytic enzymes
3. The cord which helps in the attachment of the embryo to the placenta. umbilical cord
4. The part where the egg is fertilized.

IV. *Give reasons :*

1. Usually only one sperm fertilizes the egg.
2. After the child's birth the umbilical card is tied and then cut!
3. Man is heterogametic.
4. Identical twins are exactly similar to each other.

● ● ● ●

CHAPTER 8

Microbes and Man

We see around us various living forms, from tiny insects to huge trees several meters high. The smallest article a normal human eye can see is about one tenth of a millimetre (100 microns). To see smaller objects you may need magnifying glasses and to see very small objects more powerful tools like microscopes are necessary. The discovery of the microscope opened up an entirely new world to man. It revealed the existence of extremely tiny living organisms. Initially the realisation of the existence of these microorganisms and their study was a mere curiosity but we soon realised that the microbes play a crucial role—that they are the cause of human suffering as well as happiness and in a way responsible for the continuance of all life on earth. Thus the study of microbes (called microbiology) has not only added to our happiness, it has profoundly affected our way of life and thinking. For instance we know now that a number of diseases are caused by micro-organisms that can be controlled and are not due to any divine curse. In addition various principles of biology and biological phenomena can be investigated and understood by using microorganisms as model systems.

Under micro-organisms we usually include the unicellular forms like bacteria and the blue-green algae (now also called as cyanobacteria), green-algae, protozoa and fungi. The viruses which are not strictly cellular forms are also often included under micro-organisms.

5*

Micro-organisms occur nearly everywhere and show widest range of adaptation. They occur in deep ocean bottoms and on top of high mountains. They are found in polar icepacks and in hot water springs at nearly boiling water temperature. Those with very little tolerance of salt to those that occur in the Dead sea ; from highly aerobic to obligate anaerobic forms. Some can grow in simple solutions containing only inorganic compounds, some may require several nutritional supplements like amino acids, vitamins etc. Some obligate pathogens will not be able to grow and survive outside their hosts. Because of their versatility, it is possible for one to obtain organisms with any specific property. By suitably adjusting the composition of the nutrients in the medium and other environmental conditions, we can selectivly enrich and isolate the specific type of microorganism we want. Such methods are called *selective culture* or *enrichment culture* methods.

Robert Hooke in 1665, who perhaps made the first compound microscope, saw and described cells in a piece of cork and established that bodies of plants and animals are made of simpler repeating elements which he called " cells ". Though not the first to observe, the first to make accurate, detailed and vivid descriptions of micro-organisms was Antonie Van Leeuwenhoek (1632–1723) who lived in Delft, Holland. During his life time he wrote several letters to the Royal Society of

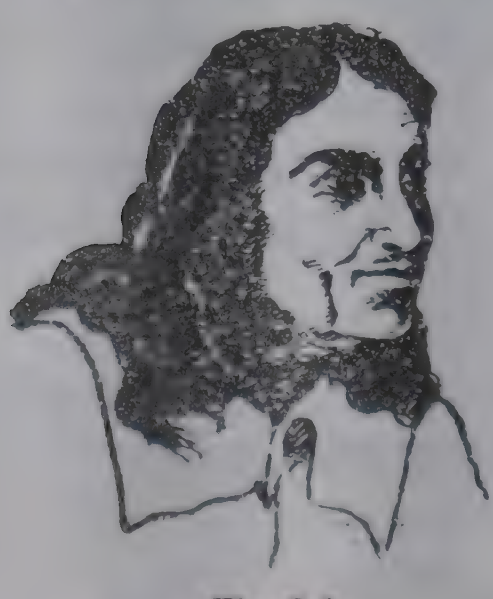


Fig. 8.1
Antonie Van Leeuwenhoek

London, describing in detail several microorganisms that he had observed in pond water, scum from teeth etc. His descriptions were so accurate that it is possible to recognise them easily. He affectionately called them "animalcules".

Leeuwenhoek described bacteria, protozoa and other microscopic organisms. For nearly two centuries after their discovery there was no progress in microbiology. It had to wait for developments in microscopy and chemistry, when rapid strides were made and the involvement of micro-organisms in every aspect of life on earth was realized A few names standout in these studies, and mankind for all times to come owes them a lot. Among these we can include Louis Pasteur, Robert Koch, Winogradsky, Jenner, Lister and others. Their discoveries changed the whole philosophy of man for they showed that epidemics, natural cycling of matter, fermentations etc. are due to microbial activities and not due to any supernatural interference in our activities. We will now study the contributions of a few important microbiologists.

Louis Pasteur

A French scientist, he contributed to several branches of science. He showed that fermentation of wine etc., are brought about by yeasts, and that another group of organisms are responsible for the spoilage (souring) of wine. He established the existence of anaerobic life-and in fact defined "Fermentation is life without air". He also showed that the

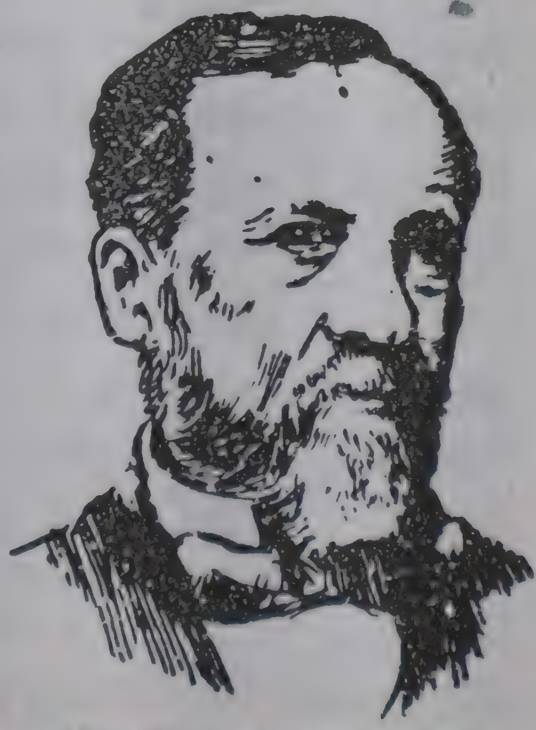


Fig. 8.2 Louis Pasteur

bacteria responsible for spoilage can be killed by heating, a process now widely used and appropriately called *Pasteurisation.*

Another important contribution of Pasteur, that has great relevance to Karnataka, is his finding that the dreaded disease, *pebrine* of silkworms is caused by a protozoan called *Nosema bombycis* and the disease is transmitted by infected female moths. He developed methods for examining the moths and preparation of disease-free layings. Even now essentially his methods are being followed in the grainages. Pasteur studied diseases of chicken, sheep, and cattle and developed the whole concept of immunisation. He saved thousands of animals from anthrax by immunisation. Now immunisation has become a routine practice. It was Pasteur who developed the general concept that an individual can be made resistant to a disease if he is treated with inactivated or *attenuated* pathogen. Another glorious contribution of Pasteur is the cure for the horrible disease 'rabies' usually caused by mad dog bites. The organism could not be seen under microscope or cultured, yet the disease could be produced by injecting the saliva from mad dogs. Pasteur prepared a vaccine against rabies. Later the causative agent was identified as a virus.

From infected rabbits, the brain and the spinal cord, were removed and dried for several days and powdered. Pasteur suspended this powder in glycerine. Injecting this mixture Pasteur could protect dogs from rabies. You can imagine the predicament of Pasteur when a farmer requested Pasteur to treat his son Joseph Meister who had been bitten by a rabid dog. For vaccinating dogs is one thing, treating a sick boy is another. To everyone's surprise

the young boy recovered. Years later Joseph Meister worked as a janitor at the Pasteur Institute in Paris. Now we have more sophisticated and improved methods of producing the antirabies vaccine.

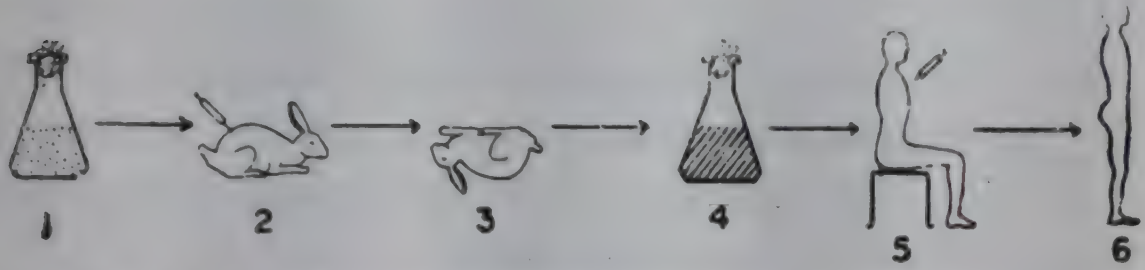


Fig. 8.3 Treatment of rabies patient with rabies vaccine

1. Saliva from rabid dog.
2. Rabbit injected with saliva.
3. Rabies develops and the rabbit dies.
4. Brain and spinal cord is extracted and attenuated.
5. Attenuated extract is injected into rabies patient.
6. Patient recovers.

Thus Pasteur established the universal applicability of what Jenner had showed with small pox about which you will learn shortly.

Robert Koch

While Pasteur was working in France, significant advances in microbiology were made by Robert Koch in Germany. He made important contributions to basic techniques for the isolation and purification of bacteria particularly the pathogens. He established rigid criteria for proving unequivocally that a

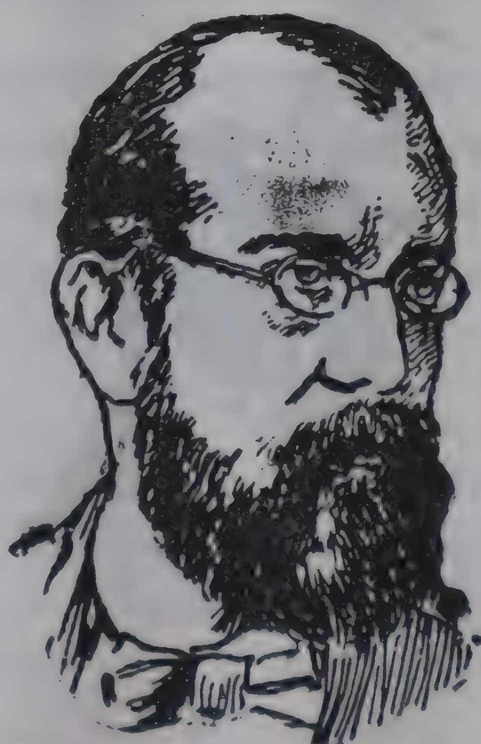


Fig. 8.4 Robert Koch

particular organism is the cause of a particular disease. Though these concepts were already known in a general way, Koch refined and stated them in a clear manner. Hence these are popularly known as Koch's postulates. Briefly these are :

1. The alleged organism must be present in the diseased individual.
2. The organism must be isolated and grown in the laboratory in a pure form.
3. When the laboratory grown organism is injected into healthy animals, it should cause the same disease.

4. From such experimentally diseased animals, the inoculated organism must be reisolated.

Koch worked on a number of diseases and notable among these is the isolation of the causative organism of tuberculosis (*Mycobacterium tuberculosis*)

Joseph Lister

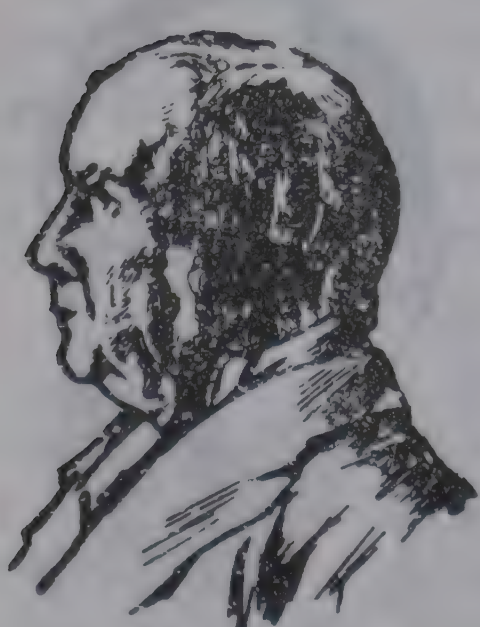


Fig. 8.5 Joseph Lister

Pasteur's ideas on the role of microbes in fermentation, spoilage and diseases so inspired a British surgeon Joseph Lister, he advocated the use of dilute solution of phenol to prevent infections after operations and cleaning of wounds and thus the importance of antisepsis and disinfection was fully appreciated. While it is important to recognise the good organisms and make them do useful

things for us, it is equally essential to know the 'bad' ones and control or prevent their growth. To this end a number of methods were developed and chemical methods are the most important.

Micro-organisms could be controlled—*i.e.*, removed, killed or prevented from multiplying by physical or chemical methods. In this it is good to know the following terms and their definitions.

Sterilisation is the process of destroying all forms of micro-organisms. So in a microbiological sense a *sterile* object or medium is free of all living organisms. Hence the term is absolute and cannot be used in a relative sense. A material is either sterile or not sterile it is never *almost* sterile. *Disinfection* is the process of destroying infectious agents. A *disinfectant* is an agent (usually a chemical) that kills growing forms and not necessarily the resistant spores. Also the term is usually applied to agents used on inanimate objects (*eg*. floors, table tops, instruments, vessels, etc).

Antiseptic is a substance that prevents sepsis and other actions of micro-organisms by killing them or by inhibiting their growth and activity. As against "disinfectant" *antiseptic* is associated with substances applied to body surfaces (skin, mucous membrane, etc). They may not be safe enough to be taken internally.

From the above we see that there are agents that kill the organisms and there are others that only prevent their growth. The former are called "cidal" and the latter "static" agents. (adj, form cidal, noun form cide). Thus, used with an appropriate prefix, we can use the terms bactericide, fungicide, viricide, nematicide etc. What would

you call the agents that kill (a) spores, (b) alga ? The general term of germicide can be used to indicate any agent mentioned above. Some important antimicrobial agents are given in Table 8.1.

Table 8.1. Some chemical agents used for controlling micro-organisms.

Chemical agent	General use	Limitations
Phenol and phenolic compouds.	General disinfectant	antimicrobial activity restricted, irritating.
Iodine	Skin disinfectant	Irritating to mucous membranes
Ethyl alcohol	Skin and thermometer antiseptic	restricted activity.
Chlorine	water disinfection	Inactivated by organic material, objectionable taste and odour.
Silver nitrate	Treating burns	Irritation
Formaldehyde	Sterilising instruments, Fumigation.	Poor permeation, corrosive.

Chemicals can also be taken in internally to cure diseases. Among the new class of antimicrobial substances now commonly used are what are known as antibiotics. The term which strictly means 'against life' is used to denote substances produced by microorganisms that have an inhibitory effect on other microorganisms. There are a number of antibiotics known but the most widely used ones are penicillin and streptomycin.

Most of you must be familiar with the drug called penicillin. In a way it can be said this is the first antibiotic to be discovered that had a revolutionary effect on the practice of medicine. This is produced by the mould called *Penicillium notatum.* Alexander Fleming discovered this mould produced substances that can inhibit pathogenic bacteria. Later Howard Florey and Ernst Chain purified the substance and established its chemical nature and its therapeutic usefulness. For these contributions all three were awarded Nobel Prize in the year 1945. Then penicillin was called the miracle drug.

Selman A. Waksman was deeply interested in the study of an interesting group of soil microorganisms called the *Streptomycetes.* He found that many of them inhibited other microorganisms. From the culture of *Streptomyces griseus* Waksman and his associates obtained streptomycin, a very valuable antibiotic used against tuberculosis. There are a number of antibiotic factories in India namely at Pimpri, Baroda, Rishikesh and other places.

Now let us look at some important diseases of man and animals.

Viral diseases

Viruses are extremely small parasites on plants, animals and even microorganisms. These can grow only on other living cells but many of them can be kept viable outside a living cell for long periods. Viruses are not cells and the virus particles are inert by themselves. When they become associated with their proper hosts cell they begin to function. At that time the virus is supposed to infect the cell and is able to reproduce using the machinery of the host cell.

By themselves they can not use food for energy and have no capacity for independent metabolism.

We have already seen rabies—a viral disease affecting the nervous system which is transmitted by the biting of infected animals.

The diseases viruses cause include small pox, chicken pox, measles, mumps, polio, encephalitis, influenza, yellow fever, herpes etc. Rinderpest and foot and mouth disease are the more important cattle diseases. The silkworms which are of economic importance to Karnataka, are also prone to viral diseases.

Many plant and animal viral diseases are transmitted by arthropod vectors (agents). For instance Japanese encephalitis and yellow fever are spread by mosquitoes.

Smallpox

Small pox was a dreaded disease for long time causing high mortality. Caused by a DNA virus, the disease is highly contagious. Edward Jenner (1796) infected a boy James Phipps with material obtained from cowpox lesions from the hands of a dairy maid. Six weeks later when the boy was infected with pus from a small pox victim, no disease developed. Jenner repeated the experiment several times and found that infecting people with cow pox protected them from small pox. Thus Jenner could save several people, and he called the procedure "vaccination."

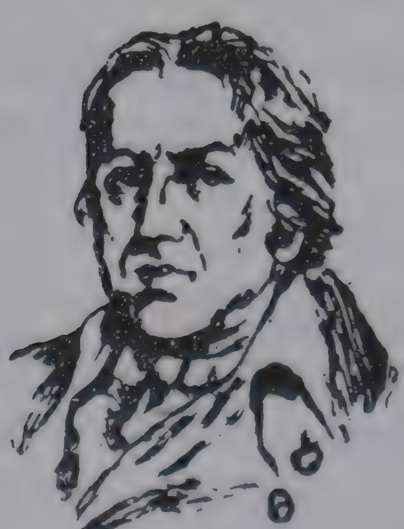


Fig. 8.6 Edward Jenner

Vaccination is a process of immunising man against the diseases

(From Latin *Vacca* cow; when the small pox virus *Variola* itself was used the practice was called variolation). Now the term is used rather generally for immunisation itself. Today small pox has been completely eradicated from several countries including our own. This was achieved due to intensive small pox eradication programme started in 1973 and by 1975 small pox was completely eradicated in India.

Pasteur's studies with rabies gave rise to methods of attenuation (*i.e*, making a pathogen less virulent). Today viruses are cultivated in chick embroyo, or cell cultures grown in the laboratory.

Poliomyelitis or Polio

Polio is another accursed disease of mankind. The virus can spread by food or water. It is caused by an extremely small RNA virus. The virus has affinity for nervous tissue and has a very narrow host range. As such the only natural source of the virus is man. There can be infected persons with no paralytic manifestation who may be excreting the virus. The virus they excrete enters the new host by ingestion or inhalation.

In the new host the virus invades the lymphoid tissues in the upper respiratory tract or certain regions in the small intestine. In the next few days large amounts of virus are produced till there is a spill over and invasion of the blood stream. In severe cases there can be death. After a phase of invasion of the blood (viremic phase) the virus infects the nervous tissue and in serious cases paralysis may occur. It is possible to arrest the process before the virus reaches the nervous tissue. Only when critical areas are affected paralysis occurs. It is possible that host's defence mechanisms

may be able to overcome the virus infection. Generally immunity is permanent to the strain causing infection and antibodies are formed early in the infection.

It is difficult to prevent the extensive dissemination of the virus and the only effective way to control the disease is to raise the immunity of the population. Active immunity against poliovirus is achieved by the use of (a) inactivated poliovirus (Salk) or (b) live attenuated poliovirus (Sabin).

(a) The former was developed by Jonas Salk and is commonly used. Poliovirus is grown in cell cultures and is inactivated by exposure to formaldehyde. The killed virus is tested for live virus and for other organisms and is used as a vaccine. The Salk polio vaccine can be used with other vaccines like the " triple vaccine ".

(b) *Live attenuated poliovaccine* Sabin developed special strains of poliovirus that are so attenuated that they lack all power to produce paralysis even when injected directly into the brain of monkeys. These strains were obtained by continuously cultivating the virus in cultures till all neurovirulence was lost. Live attenuated polio vaccines have an advantage in that they can be given orally and the dosage required is also much smaller than the Salk vaccine which must be injected. In infants, a drop can be directly placed in the mouth. The use of live attenuated vaccines have been employed successfully in immunising whole populations.

Encephalitis

There are a number of human and animal viral pathogens that are transmitted by insects and other arthropods. These are called arboviruses (short form of *arthropod borne* viruses). Mosquitoes, ticks and mites are

usually involved in transmission. These viruses can have host animals other than man. Encephalitis is an important disease caused by an arbovirus. The disease may start with a fever which progressively becomes more severe with headache, nausea etc., together with increasing involvement of the central nervous system (CNS). Stupor, paralysis and coma may occur in severe cases. Among the different types of encephalitis known, Japanese Encephalitis (JE) is more common in Asia. Although most infections are mild about one in 500 infections develop severe encephalitis. Mortality can be as high as 90%. Mental impairment and paralysis also occur. It has occured in epidemic form in different parts of India. Birds particularly herons are the wild vertebrate hosts. Pigs are also infected and undergo inapparent infections. The transmission is through mosquitoes. It is only in man the severe clinical disease occurs. There is really no cure known and a good vaccine is yet to be developed. So the disease can be only checked by controlling the vector — the mosquitoes. Steps must be taken to prevent the breeding of mosquitoes. Pesticides can be used for this purpose with caution.

Bacterial diseases

We have already seen the basic definition of bacteria. These are unicellular and morphologically they can be spherical (coccus — pl. cocci), rods (bacillus — pl. bacilli), curved or spiral (spirillum) or helical. Some of them are motile with appendages called flagella (sing. flagellum). Again the location of the flagella also helps to identify the organisms.

We have earlier seen the contributions of Pasteur and Koch to bacteriology, and the role bacteria play in human welfare and maladies.

We will now see some of the important diseases caused by bacteria.

Airborne infections

Many diseases affecting the respiratory tract are airborne and frequently may occur in an epidemic form. Their incidence may also increase during seasons when people are likely to occupy crowded areas. The causative organisms are transmitted principally by direct association through secretions of nose and throat etc. of infected individuals by cough, sneeze or indirectly through articles (hand kerchief, drinking glasses etc.) handled recently by infected individuals.

Diphtheria

It is an acute infection and is caused by the bacterium *Corynebacterium diphtheriae.* While the organisms generally are confined to the throat, tonsils and nose, they produce a very powerful toxin which circulates throughout the body. The throat may be covered with shiny 'pseudomembrane' The disease generally becomes noticeable 2 to 5 days after infection as sore throat and fever. An exudate forms in the throat and in nonimmunised cases this exudate may become membranous and clog the respiratory passage If not properly treated the case may become fatal. Anti-toxins can be given to neutralise the effect of the toxin.

For production of anti toxin a suitable virulent strain of the pathogen is grown in a broth medium at 36° C for a week Under suitable conditions the organisms will grow rapidly and form a scum on the surface. The toxin-containing liquid is obtained by passing through filters that will detain

all microorganisms. The toxin can be converted into a toxoid by treating with formaldehyde and precipitating with alum. By this method the toxic property of toxin is destroyed but its ability to induce antibody formation is unaffected. The toxoid is injected into healthy horses to stimulate the formation of antibodies. After the horse is immunised, blood is collected from the horse, allowed to clot and the serum is separated and used.

The disease is highly infectious and usually spread directly from person to person. It mainly affect children and it is essential that all children are immunised before the first birthday. Penicillin can be given for the cure of diphtheria.

Whooping Cough

Whooping cough is an acute infectious disease which is caused by a short bacterium called *Bordetella pertussis.* There is a characteristic cough, ending with a crowing sound or whoop. Haemorrhage of the nose, eyes and even the brain may occur. The inability of the patient to eat or retain food leads to malnutrition and further complications. The presence of the organism in the sputum is a good indication. The disease is primarily a childhood disease and 85% of deaths caused by whooping cough occur in children below 2 years. Vaccination is an effective way of prevention and the pertussis vaccine is given along with *diphtheria* and *tetanus* vaccines.

Tetanus

Clostridium tetani generally grows in deep and ragged wounds with dead tissues. The growth of aerobic organisms in the region actually provides the anaerobic conditions for

the pathogen, which produces a water soluble toxin. The toxin when it reaches the central nervous system causes painful contraction of muscles usually of the neck and jaw. Opening of the mouth is hindered giving the disease its common name 'lock jaw'. While *C. tetani* can exist as a saprophyte and is widely distributed, infection occurs whenever a laceration or wound comes in contact with soil or any contaminated material. Now prophylactic immunization with the toxoid is possible and as stated earlier children are immunized against tetanus along with diptheria and whooping cough.

Plague is a bacterial disease transmitted by rat flea *Xenopsylla cheopsis* and is caused by the bacterium, *Yersinia pestis.* It was once a very fatal disease causing nausea, fever and vomiting. As stated above the disease is transmitted by the bite of rat flea, which acquire the pathogen by biting rats or other rodents which act as reservoirs. Prophylactic immunization which lasts for 6 to 12 months is possible but the control of plague also depends on the control of rodents and fleas. But this is difficult to accomplish, so isolation of patients, avoiding contact with rats, proper disinfection of fomites and discharges of patients are essential to prevent spread of the disease.

Tuberculosis and Leprosy

Tuberculosis is a chronic infectious disease and may still be the cause of death in several developing countries. Robert Koch in 1882 isolated the causative organism *Mycobacterium tuberculosis.* Human tuberculosis may affect any tissue of the body but the lungs are the most commonly affected. Since it is a chronic disease initial infection may go unnoticed. The general symptoms are pleurisy, chest pains and coughing and afternoon fever etc.

The formation of 'tubercle' or small nodules formed by the body cells in response to the pathogen or its products is the basic lesion of the disease.

Treatment till recently was only nice rest in healthy pleasant surrounding with nutritious diet. Nowadays good drugs are available. Since the disease is chronic, the treatment is also prolonged. Streptomycin (an antibiotic), para amino-salicylic acid (PAS), isoniazid (isonicotinic acid hydrazide INH) are the drugs of choice and are more effective when given in combination.

Leprosy is another chronic disease caused by another mycobacterium, *M. leprae*. Dr. Hansen in 1874 established the etiology of leprosy. The lack of knowledge about the disease has resulted in unnecessary fear and social attitudes which must change. If detected and treated early the disease can be cured before any one else comes to know of it.

The disease affects the skin and nerves. A faint pink patch on the skin, with loss of sensation to touch, heat or cold is indicative of the disease. If not treated immediately the patch may increase in size and new patches may appear. This region may have no perspiration or scratching sensation. If the disease further advances some of the organs like finger tips, ear lobes etc., may get sloughed off and deformity occurs. There is plenty of ignorance about the disease and it is good to know the following facts :

1. It is not a hereditary disease, and if children born of leprosy patients are separated and brought up they will be healthy and normal.

2. The disease is *not* as infectious as it is believed to be. In fact it requires repeated intimate contact to spread from person to person.

3. *Leukoderma*— a physiological disorder is often mixed up with leprosy. Leukoderma is due to defects in the pigment forming mechanism in the skin. It is not caused by any pathogen and is not infectious.

Ignorance about the cause of the disease makes many people neglect proper treatment, which allows the disease to advance ending in the disfigurements that are seen.

It is incorrectly believed that a person who has contracted leprosy is doomed. The relatives and friends instead of showing understanding and help try to boycott a leprosy patient which is wrong.

There are now some drugs available which can be used for cure and as a prophylactic against leprosy. Oral administration of sulphones-particularly dapsone and acedapsone are commonly used against leprosy. Proper detection and undergoing treatment will prevent leprosy, and every one must strive for it. As mentioned earlier, one should not have an exaggerated fear of the disease, nor ignore proper treatment.

We will now study a few common food borne infections *i.e.* cholera, typhoid, botulism, dental caries, hepatitis.

There are a number of infections where the pathogens enter and leave through the oral-intestinal route and are also called enteric infections. Transmission is through food and water which may be indirect *i.e.*, wastes from infected persons may be permitted to pollute drinking water or food or persons harbouring the organisms may handle the food

and contaminate it. The common house fly is also frequently responsible for transmitting enteric organisms from wastes to food. As you can readily see, the control of intestinal infections to a very great measure depends upon preventing contamination of food and water by arranging proper sanitary measures and purification of water. Quite a few epidemics may result through water pollution.

Cholera

It is popularly known as *Asiatic cholera* because it is endemic to India and south east Asia. The disease, caused by a comma shaped bacterium *Vibrio cholerae* is of great antiquity and has caused untold suffering for several centuries in India. The disease runs its course in 2–3 days and the symptoms include acute diarrhoea, vomitting resulting in severe dehydration. Replacement of fluids, salt and carbonate is essential to treatment.

V. cholerae is transmitted by contact and food and water contaminated with excreta. Sulfonamides and antibiotics may be useful in therapy.

Immunization with vaccine gives protection for 3 to 6 months. Those travelling to areas where cholera is present should be vaccinated. An efficient sanitation is usually preferable to immunization. Yet in India where during certain festivals lakhs of people gather it is better to immunize the people as a preventive measure.

Protozoal infections

The protozoa cause several diseases in man and other animals. The more common and important ones are amoebiasis, malaria and sleeping sickness.

9

Amoebiasis

Though a number of protozoa have been seen to cause intestinal infections, the greatest incidence is due to *Entamoeba histolytica.* Like other intestinal disorders the disease spreads mostly through contaminated food and water. Persons with amoebiasis may show few clinical symptoms or they may display symptoms that are wide ranging from slight abdominal discomfort with mild diarrhoea alternating with constipation to severe dysentery. Careful identification of the carriers and prevention of contamination of food will be required.

Malaria

Malaria is among the more pernicious and debilitating diseases of man. There is a very high incidence of infant mortality. For a long time it was not known how the disease spread. The painstaking studies of Sir Ronald Ross revealed the role of the mosquito in the transmission of the disease. He also showed that part of the life cycle of the pathogen takes place in the mosquito, which incidentally is a protozoan called *Plasmodium.* The sporozoites which are released into the hemolymph accumulate in the salivary glands of the mosquito and when it bites a healthy person these are injected into the blood. There they undergo a primary cycle of growth in the liver and then a cycle in the erythrocytes in the blood and may be acquired by a mosquito when it bites an infected

Fig. 8.7. Ronald Ross

person. Malaria is spread by mosquitoes belonging to *Anopheles* and only female mosquitoes are involved in the spreading of the disease.

The symptoms of malaria are essentially due to the growth of the parasite in the erythrocyte cycle. The onset is sudden fever and there is periodical fever and sweating—the malaria rigor. The recognition of the parasite in the blood is an important step in diagnosis. In the case of developed disease chloroquine and amodiaquine are useful drugs. The natural drug quinine is efficacious though it has been now largely replaced by the above synthetic drugs.

Malaria can be more effectively controlled by preventing the breeding of mosquitoes. This can be achieved by keeping the environment clean, preventing the formation of stagnant water and cesspools. The use of insecticides over stagnant waters is useful. A concentrated attempt by the World Health Organisation (W.H.O.) and our Government's National Malaria Eradication Programme have largely reduced the incidence of malaria though in the recent years malaria incidence is on the increase. This is sometimes attributed to the development of resistance to the insecticides by the mosquitoes, particularly to D.D.T.

Chaga's disease and sleeping sickness (American and African Trypanosomiasis respectively) are other important protozoal infections of man. The former is transmitted by certain blood sucking bugs and the latter by tsetse flies. (Fig. 8·8 gives a general illustration of transmission).

Defence against Disease

The above description of different diseases might lure you to think all microbes are vicious pathogens. On the other hand of the several hundreds of microbial species most

Fig. 8.8. Different ways of transmission of pathogens from person to person

(i) Infected Host (ii) New Host

(1) Human to Human (2) Through vectors (3) Direct contact
(4) Indirect through food, water, contaminated articles etc.
(5) Pathogen multiplies in the vector.
(6) No multiplication of the pathogen in the vector
(7) From animal host through bites etc.

are innocuous and in fact several are beneficial as we shall see a little later. Only a few are pathogens. In spite of the fact the pathogens are everywhere most of us do not generally fall ill. While the pathogen uses different means to establish infection the host body has a number of defence mechanisms to prevent it. It is in the final outcome of this intricate host pathogen interactions, the survival or succumbing of the host lies (*See* figure 8.9).

The ability of a host to overcome or prevent infection by pathogens is known as *resistance* and *immunity* and the lack of such resistance is called *susceptibility*. The

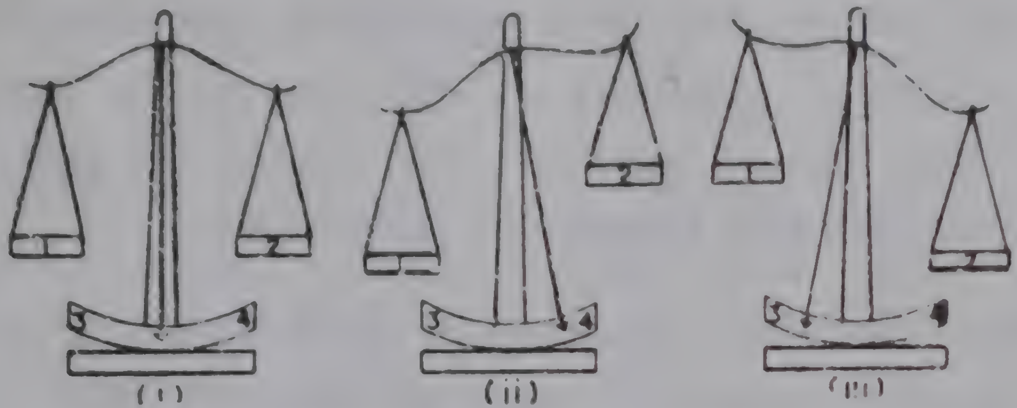


Fig. 8.9. Host-pathogen relations in health and disease.

1. Susceptibility factors   3. Health
2. Resistance Factors   4. Disease

(i) Balance—results in good health.
(ii) If susceptibility factors exceed resistance factor disease results.
(iii) If resistance factors exceed susceptibility factorss pathogen is overecme—good health results.

immunity or resistance are commonly referred to be either *natural* or *acquired*. The natural resistance is due to defence against infection by a number of mechanical and chemical barriers. The skin and the mucous membranes, mucous secretions, enzymes, and various components of the body fluids which are antimicrobial are all examples of such barriers.

The unbroken skin and mucous membranes provide an effective barrier to germs and the various acids in sweat and sebaceous glands of the skin inhibit most bacteria. Besides most body secretions like mucous, saliva, tears in addition to mechanical flushing of bacteria also contain antimicrobial substances for example lysozyme which destroy

bacteria. Epithelial cells lining body cavities and orifices (throat, nose) contain small hair like structures called *cilia* and sweep away germs from susceptible areas, and these are expelled when we cough or sneeze or salivate. The acidity or alkalinity of the body fluids have their deleterious effect on bacteria. For instance the high acidity of the stomach kills several microorganisms.

While the above mechanisms can be called as external defence mechanisms, we have at the next level internal mechanisms. The internal mechanisms can be *nonspecific* or *specific*. The nonspecific mechanisms are due to *phagocytosis*, where the neutrophils (a type of white blood corpuscles) and macrophages gobble up and digest bacteria and other foreign particles. The importance of phagocytosis as a mechanism of protecting the body from disease was first recognised by Elie Metchnikoff in 1882. The specific mechanisms are due to the production of *antibodies*. Whenever microorganisms or other foreign bodies enter the body certain specialised cells recognise them and produce what are called antibodies. These are complex proteins and are *specific* to the agent (*antigen*) against which they are produced. Thus antibodies can be produced against microbes or their secretions or the toxins produced by them. Antibodies produced against toxins are also known as antitoxins. These combine with the toxins and neutralise their toxic effects. Antibodies produced against one organism will not act against another organism and this holds good for antitoxins too. Once a host has been exposed to a particular microbe or toxin and

antibodies have been formed the host is now said to be immunized. If the same agent enters the body sometime later, the antibodies present in the blood can readily combat them. Further more antibodies can be readily formed at a fast rate.

This is the reason why people do not contract many diseases (i. e. small pox) more than once. This type of acquired immunity can be artificially induced, as we have learnt earlier by injecting attenuated or killed cells into hosts and is called *active* immunity. Acquired immunity can also be *passive*. Here antibodies produced by active immunisation in one individual can be transferred to another. This method gives immediate but temporary protection (Table 8.2).

Table : 8.2. Types of Acquired Immunity.

Type	Source	Degree and duration
Active	Antibodies produced by the body as a result of stimulation by living, killed or attenuated organisms or their products.	Takes time to develop at the first instance ; Usually complete and enduring.
Passive	Antibodies produced by active immunity in one individual are transferred to another.	Provides immediate but temporary protection.

The following chart summarises the defence mechanisms present in a host.

Defence Mechanisms

Natural Resistance

- External Mechanisms
  - Skin; Mucous membrane and other mechanical barriers
  - Coughing Sneezing Sweating
- Internal Mechanisms
  - Nonspecific
    - Phagocytosis
      - Lysis
  - Specific
    - Antibody Production

The Beneficial Micro-organisms

We have mentioned earlier that the microbial activities are essential for our survival. This is due to various factors. For instance plants use CO_2 and sunlight to make carbohydrates. They also use other minerals from the soil. All other animals depend upon plant life. While on the one side dead bodies of plants and animals can accummulate, continued photosynthesis can deplete all CO_2 in a few years making plant life itself impossible. Here the micro-organisms play a very important role. They decompose all dead tissues. In this process they not only destroy harmful wastes, they release back into the environment CO_2 and also the locked up minerals in the tissues. This ability of the microorganisms can be successfully used in the treatment of sewage and other industrial effluents The microbial activity decomposes all organic matter in

sewage and if properly done kills all the pathogenic micro-organisms. This capacity is also utilised in the conversion of crop and cattle wastes into compost and farmyard manure. In short CO_2 and other inorganic substances are converted into organic materials by algae and plants and they are converted back to inorganic materials by microbial action (called mineralisation).

In view of their versatility in the decomposition of organic matter and in the recycling of elements they are of great importance in agriculture. But one should be aware that the versatility of the microbial world *as a whole* should not be mistaken for the ability of any particular individual. Any single species will have only a restricted role to play in mineralisation. It is often noticed each specific step may be brought about by specific group or species of micro-organism. We will study in brief the nitrogen cycle.

The Nitrogen Cycle

Though the earth's atmosphere contains nearly 80% nitrogen, it is inert and cannot be used by plants and animals, except by a few prokaryotic organisms. All other forms of life require some form of combined or fixed nitrogen. Since combined nitrogen is relatively less abundant, nitrogen becomes the most limiting nutrient. The main features of nitrogen cycle are depicted in Fig. 8.10.

The turnover of nitrogen through the nitrogen cycle is estimated to be abont 100 to thousand million tons. All the combined nitrogen that is formed due to lightning, electrical equipment and the industrially produced fertiliser

nitrogen will amount to less than ten per cent. The remaining combined nitrogen is due to the activities of prokaryotic microorganisms. So this conversion of gaseous nitrogen to combined nitrogen is called *nitrogen fixation*. Biological nitrogen fixation is restricted to a few prokaryotic organsims, which convert atmospheric nitrogen to ammonia and then incorporate it into their

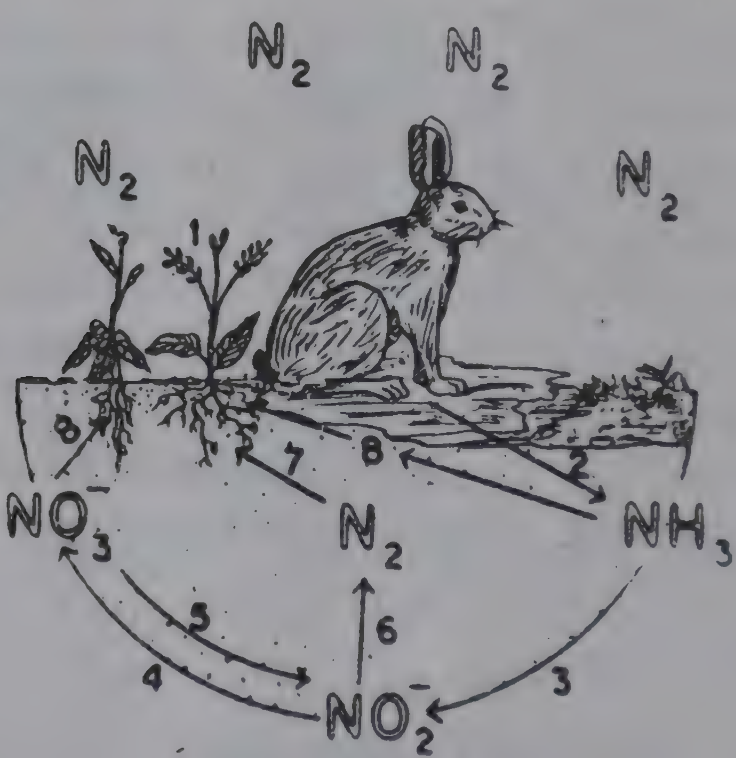


Fig. 8.10

(1) Organic nitrogen in living system
(2) Ammonification
(3) & (4) Nitrification
(5) & (6) Dentrification
(7) Nitrogen fixation
(8) Nitrogen uptake by plants.

cell material which becomes available to plants, etc., when they die. Biological nitrogen fixation is brought about by organisms that are free living (non-symbiotic nitrogen fixation) or by those in association with a host plant (symbiotic nitrogen fixation). Among the free living nitrogen fixers are blue-green algae like *Anabaena*, *Nostoc* and aerobic bacteria like *Azotobacter*, *Beijerinckia* and

anaerobic bacteria like *Clostridium* and photosynthetic bacteria. The classical example of symbiotic nitrogen fixation is the association of *Rhizobium* with leguminous plants like pea, beans and several pulse plants. The bacterium on entering the host plant induces the formation of root nodules inside which it fixes nitrogen. While the plant provides energy and other materials, part of the nitrogen fixed is made available to the plant. Each legume species has a specific *Rhizobium* whose association alone can bring about nitrogen fixation. Most of these rhizobia have been isolated and grown in pure culture. These can be used to inoculate the seeds before planting and thus facilitate abundant nodulation.

Nitrogen is mostly taken up by plants as nitrate and occasionally in the ammoniacal form where they are converted into organic forms of nitrogen. Organic forms of nitrogen in the dead plant and animal remains must be converted back to inorganic form. The decomposition of nitrogenous organic matter results in the formation of ammonia (ammonification). The ammonia is converted into nitrite and nitrate by nitrifying bacteria. Nitrates can also be reduced to nitrite, N_2O, N_2 and NH_3 by denitrifying bacteria.

This type of conversion of nitrogen to organic and inorganic forms is popularly known as nitrogen cycle. Similar cycles exist for other elements like carbon, phosphorus and sulphur etc.

Other Beneficial uses of Microorganisms

Various microbial processes are being exploited for the benefit of mankind. Thus they are used in the production

of various industrial acids, solvents, flavouring agents Several food products like curd, cheese, butter etc., are due to the activities of micro-organisms. A number of important drugs like antibiotics are produced by different micro-organisms. For several important industrial processes microorganisms like bacteria, actinomycetes, yeasts and fungi are used. Besides microbial action is the one exploited in the retting of fibres like jute, coir and flax, tanning of leather, curing of tobacco, coffee and cocoa.

The yeasts play an important role in the production of several alcoholic beverages and industrial alcohol. Under anaerobic conditions they convert sugars to alcohol and CO_2. The CO_2 which is obtained as a by-product can be used in several industries. A special type of yeast (bakers's yeast) is used in the fermentation of dough in making bread. Most of the alcoholic fermentation is done with yeasts belonging to the genus *Saccharomyces*. Certain yeasts belonging to genus *Candida* can be used as cattle feed and hence these are called fodder yeasts. The biogas which is becoming an important source of energy is produced by microbial action. Some micro-organisms that are pathogenic to harmful insects are also used as insecticides.

Questions

I. Answer the following :

1. What is nitrogen cycle ? Explain its importance.
2. What are the main contributions of Louis Pasteur to mankind ?
3. What are airborne infections ? Explain one.

4. *Explain the following* :

(1) Sterilisation
(2) Germicide
(3) Immunity
(4) Toxoid

II. *Fill in the blanks* :

1. Penicillin —— is the first antibiotic.
2. ~~Rabies~~ Polio —— is a viral disease affecting the nervous system.
3. Tetanus —— is known as lockjaw.
4. The toxin can be converted into a toxoid by treating with formaldehyde
5. The lack of resistance is known as ——— Susceptibility

III. *Name the following* :

1. The person who discovered penicillin Alexander Fleming
2. Soil microorganisms Streptomycetes
3. The agent which spreads encephalitis ~~Arthropod vector~~ Arboviruses
4. The bacteria which causes cholera. Vibrio cholerae
5. The man who revealed the role of the mosquito in the transmission of malaria. Ronald Ross

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6

CHAPTER—9

Animal Behaviour

All of us are familiar with some behaviour of pet animals around us such as a dog wagging it's tail on recognising someone familiar or a kitten stalking and jumping on a small moving object, training itself to catch mice. Many types of behaviour are fascinating or amusing to watch like a peacock's dance or monkey's antics, A shepherd knows the needs of his sheep by their behaviour. Very often we wrongly interpret the behaviour of animals in terms of our own feelings and attribute human motives to them. We then fear animals when there is no need to. A scientific study of behaviour is a part of biology. It allows us to understand correctly the meaning of any behaviour and how it helps the organism to survive.

What is Behaviour ?

Behaviour is the action or response of an animal in any particular situation. It may be the result of a stimulus received from the *external environment* or from an *internal body condition*. Secretion of hormones and basic biological *drives* such as hunger, thirst and sex may cause such behaviour. Such an internal state is also called *motivation*.

Behaviour of animals may be *innate* (inborn) or *acquired* (learned). Together or singly they are expressed as patterns of behaviour of animals during activities such as staking or marking outterritories, social living and during communication, reproduction, raising the young or migration.

An innate behaviour is an inborn tendency to perform such a behaviour. It is inherited like other physical traits like the colour of the eye or shape of the ear It often has a survival value for either the individual or its species. The other type of behaviour is *acquired* or *learned* during an organism's life time.

Innate Behaviour

Taxes consist of simple continuously directed movement either towards or away from the direction of stimulus. Light, chemicals, temperature and gravity are important stimuli. Many insects like butterflies, moths and grasshoppers are attracted towards light(positive phototaxis). These insects normally tolerate and are more active in light. You can attract such insects with a *light trap*. Prepare a trap (Fig. 9.1). Keep the light on the whole night and place the trap in an open place. You will find numerous insects such as moths, beetles, bugs in it the following day. All these are attracted by light. Several insects such as cockroach and bed bugs are repelled by light. They show negative phototaxis.

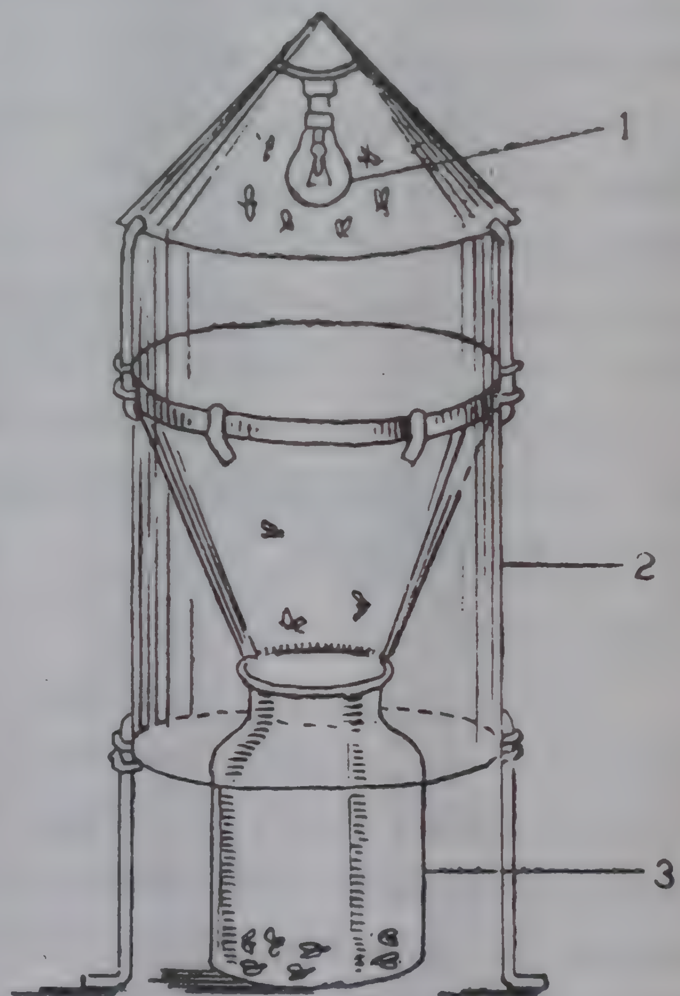

Fig. 9.1. Insect collection by light trap
1. Electric bulb 2. Outer shell
3. Insect collecting jar

Earthworm cannot tolerate bright light. At night they come out of their burrows on to the soil surface. If light shines on them they immediately retreat into their burrows. Planarians (aquatic flatworms) have two 'eyes' on their head which detect light and they swim towards light (positive phototaxis) when the water is still. When the water becomes turbulent (agitated), they swim away from light. This behaviour has a survival value. Planarians feed on floating algae found near the surface of water. In still water, the planarians move towards light and reach the surface where food is present. Under unfavourable condition when water is turbulent, they swim away from light, that is away from the surface towards the safer regions in the bottom of the pool for protection.

Reflex action

If you accidently pick up a hot object, you suddenly drop it. If someone suddenly moves his hand past your face, you blink your eyes. These are examples of *reflex action*. Reflexes control your posture, the size of pupil in the eye and so on. A reflex action is defined as an *involuntary action* in response to an external stimulus. It is an inborn automatic respone mediated by a *reflex arc* about which you studied in the chapter on *Nervous system*.

A *voluntary action* is different from reflex action as the brain is involved in this. If you see an object on the table and decide to pick it up, you reach your arm and grasp the object with your hand. Both your arm and hand respond because you direct their activity. Here the idea originates in a certain centre of the cerebrum. The impulse is transmitted by the motor neuron to bring about the desired movement. Many of our action are at first voluntary, but

are continued later as a series of reflexes. Thus you start walking as a voluntary action, but subsequently it becomes a series of reflex actions.

Instinct

An instinct is a pattern of animal behaviour that is similar in all individuals of the same species. Instinctive behaviour are evoked by certain stimuli. The song of birds, the sucking action of a human baby when something is put into its mouth, swimming by ducklings are instinctive behaviour. They are assumed to be inherited and are under genetic control. However many instinctive behaviour can be modified by learning.

Acquired or learned behaviour

Acquired behaviour is a behaviour that is learnt. There are various types of learning, occuring at different levels. Some of these are *habituation*, *conditioning*, *trial* and *error learning*, *imprinting* and *reasoning*.

Habituation is the tendency of an animal not to respond to stimuli that originally aroused a response. Ducklings stand motionless at the sudden appearance of any object overhead, but gradually become familiar to objects seen frequently, such as falling leaves and friendly birds. Habituation occurs in human beings also. You may notice the ticking of a clock for a while but not after some time.

Conditioning is a behaviour that is learnt.

If some meat is placed on the tongue of a pup that was never fed with meat before, it will salivate. This is an innate reflex action called *unconditioned reflex*. A pup that has never tasted meat before will not salivate at the mere *sight* of meat. However it will salivate at the sight of meat after it has been *fed* with meat. Salivating at the sight of

meat is not inborn, it is *learnt*. Such a form of learning is called a *conditioned response*.

I. P. Pavlov, the famous Russian animal physiologist first described the *conditioned response* in a classic experiment (Fig. 9.2). In order to collect and estimate the amount of saliva produced by a dog, he made the salivary gland duct open to the outside by surgery. On feeding meat the dog salivated which now flowed out and could be measured. Ringing a bell produced no saliva. He then rang a bell everytime the dog was presented meat. After several such trials, even when the bell was rung without the meat being given, the dog salivated. This he called *conditioning*. This behaviour could be maintained as long as the dog was given meat some time after ringing the bell. If the presentation of meat did not follow the stimulus (ringing bell), the amount of saliva produced began to decrease and finally stopped. Here the response (salivation) to a stimulu

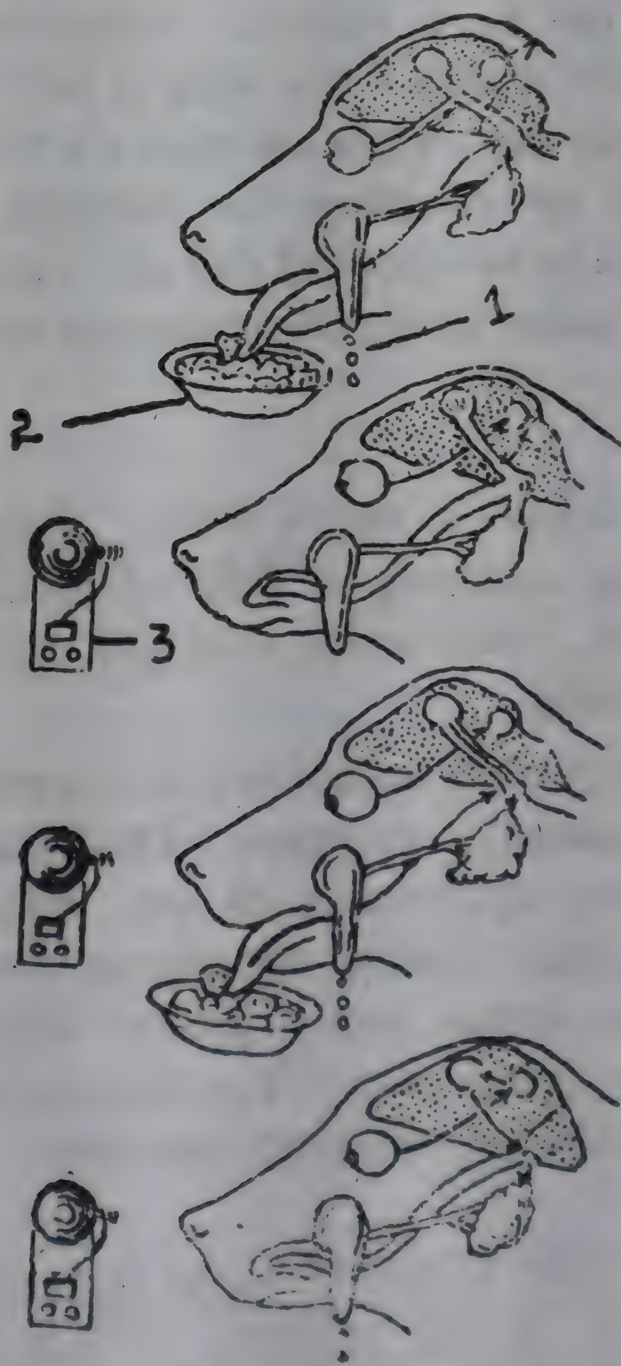

Fig. 9.2 Conditioned Response
1. Salivation 2. Food
3. Ringing Bell

Fig 9.3. Figure showing a hen with chicken

(taste of food) has been transfered to another stimulus (ringing bell) which is regularly associated with the first stimulus. The response to the second stimulus was lost if it was not *reinforced* (rewarded) with food. Conditioned responses play an important role in human and animal behaviour.

Trial and Error Learning

Have you seen newly hatched chicken ? They start pecking almost everything around. Within a couple of days they learn to peck at right things and ignore wrong objects. This is a form of *trial and error learning*. It is a kind of conditioning. If you lift a dog's paw and then put a little food in its mouth repeatedly, it will soon learn to lift the paw when it wants food. It will learn to do things for a reward. You might have seen animals performing 'tricks' in a circus. Observe that the trainer will often feed the animal with something quickly everytime a trick is

7*

performed. He is rewarding the animal, so that it may not 'forget' the trick learned by trial and error.

Imprinting

Goslings (young ones of goose), chicken and the young of certain other social birds follow their mother for a long time after hatching from their eggs. This is a way of establishing social associations and it is learned early in life by a process called *imprinting*. It has been shown that goslings, hatched in an incubator, will follow the first slowly

Fig. 9.4 Behaviour of goslings (Imprinting)

moving object particularly if it makes a sound. They may therefore follow a person whereever he goes till a certain age (Fig. 9.4).

Reasoning or Insight Learning

It is the most prevalent form of learning in the higher primates and man. *Insight* is the ability to respond correctly the first time to a situtation different from any previously encountered. The animal responds by applying what it has learnt previously in similar situations. When you see a closed gate, you open it and go in, even though you may not have gone through that particular gateway. Your earlier experience and memory helps you to know how to open that gate. Chimpanzees can use boxes to climb and

Fig. 9.5 Chimpanzee reasoning to obtain banana

reach the bananas hanging from the ceiling of a room (Fig. 9.5). But if there are no boxes, but only a person it may

climb the person and reach the bananas. Man's ability to reason is far greater than that of any other animal. He is capable of very complicated reasoning. Hence the name *Homo sapiens*, or ' man, the reasoner '.

Territoriality

Among the vertebrates and higher invertebrates (insects), individuals, pairs of individuals, family groups or large parties often confine their activities to definite areas called the *home range*. When an animal defends its home range, the home range is called its *territory*. Protection of territory is very common among most birds, reptiles, social insects and a great number of mammalian species from squirrel to man.

Territories are marked out and defended in many ways. In the African savannah, the large antelope called Uganda kob have breeding grounds. Each breeding ground of a herd has several smaller regions within it. The male of the herd fight for one of these regions. Finally one male dominates each region, the other male being chased away from it. The female kob then breeds only with those males which have secured a region for itself.

In many animals the males compete for property right and not for the female of the species. Once a territory is obtained the male animal has a psychological advantage over other males in that territory. The animals do not fight in the general grazing or food collecting areas, but only in their territories.

In certain other animals, such as the gorillas, there is only a home range and no territory is marked out by the males. So even different groups of these animals may feed in a common home range.

How big or small can a territory be? Some eagles have territories ranging over 40 miles. Others, such as some sea birds and penguins have only a token nesting place on the shore which may be only a few square feet. Herons and gulls may have territories only large enough for their nests. During the nesting season (July-November) you may see hundreds of migratory birds nesting close to each other on a single tree in Ranganathittu bird sanctuary. They may not mind close neighbours, but will fight with those who try to take a small area from them needed for building their nests.

Male birds upon choosing a territory often show off their feathers and often dance in front of females. It is called *display*. Display is often both a warning to other males to keep off a territory and also to attract the females. Song of a bird is often a way of communicating territoriality to other males. When the females arrive, they pair and the territory is established.

Why does a male bird not attack females but only other males in a territory? In some cases the reason may be due to a small difference in appearance between the males and females. The males of a bird called yellow-shafted

Fig 9.6 Black patch at the corner of t he month
A. Male Flicker B. Female Flicker

flicker has a black patch near the mouth (called moustache) which the female does not have. The male is stimulated by seeing the black patch on another male and it attacks it. If a female is similarly painted, the male will attack her. Once the paint is removed he accepts the female.

Man, like many other animals may fiercely defend his territory. While most species do not kill others of their own species, man goes to wars to defend or conquer territories. Building high fences around the house, keeping dogs to drive away intruders are other forms of protecting one's territory.

Social Behaviour

A well organised and complicated form of social life is seen among insects such as honey bees, ants and termites. The most interesting kind of social behaviour is seen among the honey bees. Let us know something about the different kinds of honey bees and the different kinds of work they do. A colony of honey bee may be made of as many as 80,000 individual bees. Out of these, one is a queen bee and about 200 are drones and the rest are workers (Fig.9.7).

The workers are smaller than the queen in size. They gather food such as pollen and nectar for all the members of the beehive. Some of the workers act as scouts and perform food dances, some remove the dead bees and dirt from the hive and keep the beehive clean; some keep a constant watch on the bee-hive, some bring fresh air into the hive by constantly moving their wings and others take care of the queen and the drones of the hive.

The only task of the drones is to fertilize the queen (once in her lifetime). Only one drone, out of the many,

accomplishes this task. Once this is accomplished, the drones may even be killed particularly if there is shortage of food.

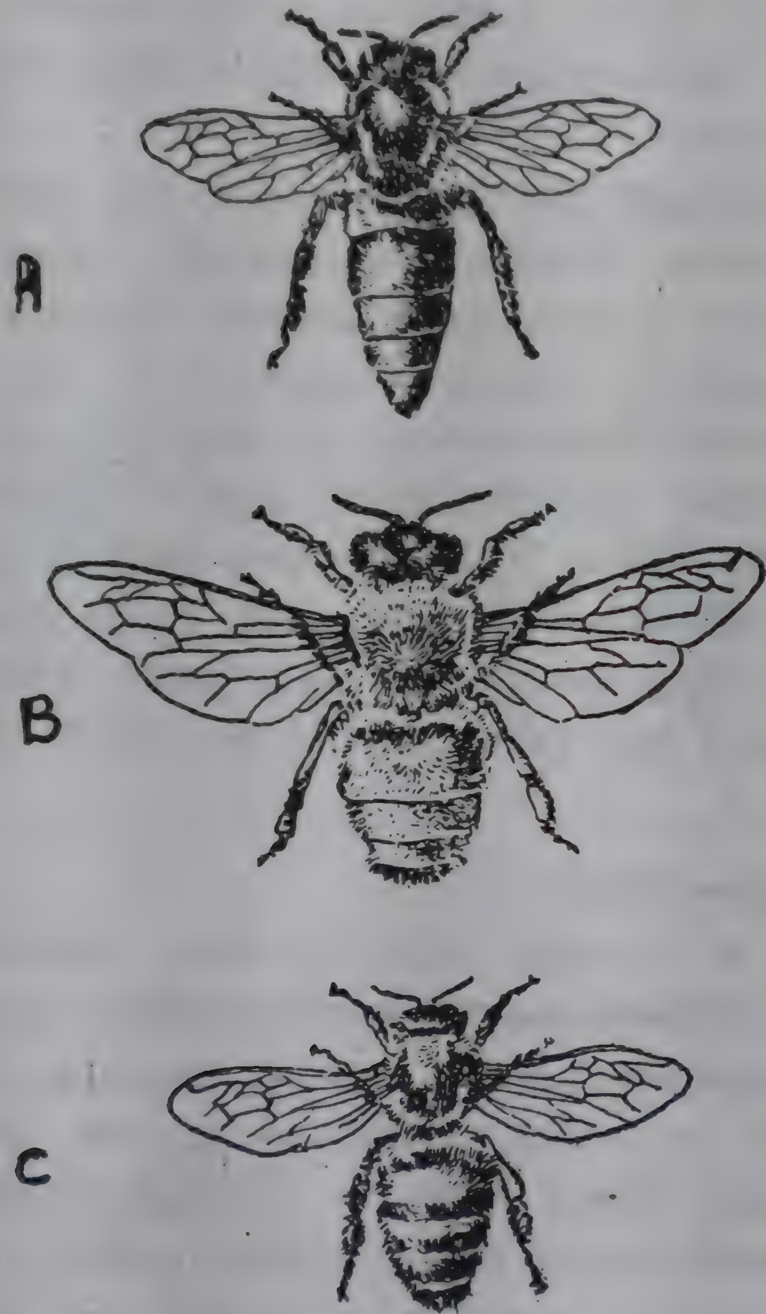

Fig. 9.7. Honeybees

A. Worker B. Queen C. Drone

The work of the queen is to lay eggs. She goes on laying eggs all through her life. The queen bee is thus the mother of all other bees in a hive. Thus they work for the common good of the colony.

Among chicken (and certain other social groups) there is a 'boss' male or cock which dominates a group. A *peck order* is also established. The more important ones can peck those below it and not in the reverse direction. This is called establishing a heirarchy. It helps in stabilizing social interaction.

Many animals like the monkeys, the gorillas, deers the zebras and the giraffes live in groups. This collective living helps them to avoid many dangers. Gorillas in Céntral Africa go about in troops consisting of one old male, several females and their babies. If attacked, the old male stands his ground, faces the enemy, and if necessary fights even to death. Then if the attack on them is continued it is the turn of the females to fight, even, to the death. Some animals like lions usually live in a family which includes the lioness and her cubs, several of which take part in hunting.

Animal Communication

Groups of animals, such as bees, monkeys, birds transmit information among members of their groups. This information tells about food sources, presence of enemies, boundary of territories, readiness to mate and so on. Communication signals may be through *tactile* (touch), *chemical*, *optical* (visual) and *acoustical* (sound) systems.

Tactile signals are usually transmitted through specific body interaction, such as one animal grasping or pushing another, although they do not actually injure each other.

Chemical signalling is the most widespread form of communication found among animals. Chemical substances employed specially for social communication are called

pheromones. They are secreted in small quantities by one animal to influence the behaviour of another animal of the same species.

Among bees, optical or visual signal are used to communicate the direction and sometimes the distance of food source. 'Scout' bees perform food dances (Fig. 9.8)

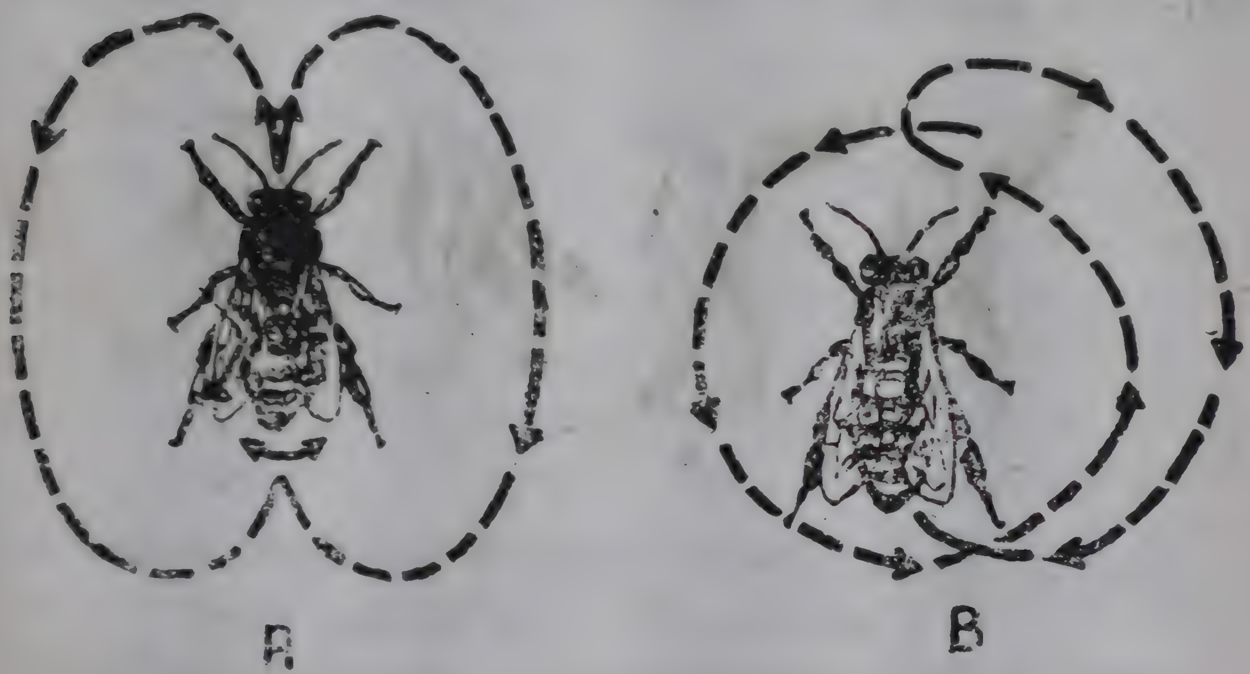

Fig. 9.8. Bee dance to communicate location of food

A. Wagging Dance B. Round Dance

on the vertical side of the honey-comb in the hive. The round dance is performed when a food source is within 8 meters. This dance contains no information concerning the direction. The wagging dance (in the form of 'figure of eight') conveys information as to both distance and direction of food sources from the hive.

Acoustical system are used to keep, herds and flocks together. Some employ sounds as signals of alarm and also a means of communicating their position. Some animals,

especially those that are social in their habits, give an 'all-clear' signal which indicates to the companions about the departure of the enemy.

Other modes of communication among animals such as posture, gait, expression convey important visual signals. A wolf's or dog's facial expression and the position of the tail informs other wolves or dogs about the mood of the individual (aggressive, submissive, confidence) (Fig. 9.9)

A B C D

Fig. 9.9. Positions of wolf's or dog's tail communicating mood

A. Confidence B. Confident threat

C. Normal position (no social tension) D. Submissive attitude

An elk, the largest species of deer found in the north of Europe and in North America, threatens his attacker by holding his head high and his ears back, while stamping with his front feet. An elk's frozen stand denotes surprise and a distinct high stepping, marching gait denote warning to other members of the herd, perhaps of the approach of a predator.

Reproductive Behaviour

The survival of the species depends upon reproductive behaviour. Varieties of communication are employed for the purpose of sexual attraction. An interesting

type of sexual behaviour is exhibited by black widow spiders. They are ordinarily solitary animals. They are cannibalistic and often prey on one another when they are confined to close quarters. For reproduction however, there must be some association and the cannibalistic tendencies are repressed temporarily at mating time.

A female, ready for reproduction will sit in the centre of her web and wait for a male, She casts out signal strands of web which are carried a considerable distance by the wind. A male follows the strand of web to her. The male is much smaller than the female and he approaches her with great caution. In preparation for this occasion the male has already removed a ball of sperm from his reproductive organs. After repeated approaches in which the female does not attempt to capture him, the male finally approaches close enough to tuck the ball of sperm into her seminal receptacle. He turns and rushes away, but the female is likely to pursue him and eat him. Thus the black spider becomes a self-made "widow" by this action. Later she lays eggs and spins a web around them to form an egg case.

The Pacific salmon fish has one of the most complicated reproductive cycles. The adults are found in salt water, but they never reproduce there. When they are ready to reproduce, which is at about seven years of age, they return to the identical stream from where they were hatched seven years previously. The eggs are then laid, the sperms released over them, and they are covered with gravel. The young ones hatch, and go back to the ocean only to return seven years later.

Acoustical system are also employed for sexual attraction. The male mosquito is attracted to the female by the sound of her wings during flight. The male frog croaks to attract the female.

Visual communication is involved in the most elaborate *courtship displays*. Among the reptiles, brightly coloured bodies are displayed and the colours serve to attract the female. A male courting pea-cock, raising his six foot multicoloured tail high over his back, approaches a hen of his choice with dancing steps, hopping from one foot to the other. Mammals use scents to attract the opposite sex. The male musk deer rubs his hind legs where the scent glands are located, against trees to alert females in the area of his presence. Cats or dogs show sex attraction with their urine which is then sniffed by other cats or dogs. Among cats and dogs it is the female that emits auditory signals to the males. Unlike other animals, human beings (man) has no definite breeding behaviour.

Parental Behaviour

Parental behaviour may be defined as any function performed either by one or both parents for the survival of their offspring.

Behaviour towards eggs

Majority of marine fishes and most of the marine and fresh water invertebrates abandon their eggs immediately after fertilization. However the parents may select safe places to deposit the eggs. Many reptiles lay their eggs inside burrows of sand and soil with a protective covering. Some insects encase their eggs in egg cocoon. Birds have a definite breeding season and start constructing nests. Birds

build their nests in the same way as their ancestors built even though they have never seen such a nest. They are complex instinctive behaviour.

Certain birds like tailor birds and the weaver birds build interesting kinds of nests (Fig. 9.10). The tailor

Fig. 9.10. Some interesting Nests of Birds
A. Tailor Bird B. Weaver Bird

bird selects two broad leaves to make a nest. The male bird makes holes at the margins with its sharp bill. Then

string-like materials are passed through the holes and the edges of the two leaves are sewn together by the female. Thus the two leaves form a tubular pocket. It is then filled with soft material and eggs are laid inside the nest. The weaver bird makes beautiful nests with coconut fibres or grass or paddy leaves. The nests are suspended downwards. There are two chambers in the nest. The upper one is for laying the eggs and the lower one is for the entrance. The light hanging nests are often illuminated by the light produced by the glowworms in their chambers.

Behaviour towards the young

One of the most important parental functions is the *feeding* of the young ones. In birds both male and female parents feed their young. Mammals possess unique feeding behaviour, nourishing their young with milk secreted from the mammary glands of the mother. An interesting type

Fig. 9.11 Basking Seal Cubs

of behaviour towards the young is found in seals. For the first fortnight the she seals feed the young ones rather heavily. When the cubs accumulate enough fat, mothers

leave them alone. The cubs for many weeks lie in the snow basking in the bright sun. After sometime having changed their coats from grey to brown they become more flexible and vivid and start their own life (Fig. 9.11).

A second behaviour pattern directed towards the young is *protection*. One of the methods of protection involves *audible signalling*. Some birds sound calls of alarm in times of danger and the chicks respond by running for a hiding place. Another type of parental behaviour is grooming. A mammalian mother cleans the young and takes off parasites and dirt.

In some animals parental behaviour is highly developed. Among lions and cheetahs, the mother undertakes a long *training* period during which the young is taught how to hunt. A kangaroo gives birth to young about the size of peanuts. They climb into the mother's pouch. The young animals live there, warm and protected and well fed till they are big enough to come out and walk.

New born puppies and kittens are blind and helpless. They must be kept in a protected place and fed on milk for quite a while before they come out and follow their mother. But a young calf gets up on its feet and follow its mother in about half an hour after it is born. This is true of all herbivores. Wild herbivores are always on the move. If their new born young cannot keep up with the herd, they would be killed by their natural enemies.

Human babies are more helpless at birth and take a longer time to grow up than any other mammal. This is required for the extensive training that they receive.

Migration

Migration is an important animal behaviour exhibited only by some animals. These animals move from one region to another with the change of seasons. Seasonal migration is one of the most interesting and complex of instinctive animal behaviour patterns. Widely diverse animals as turtles, eels, salmon, seals, birds and butterflies are migratory. Migration is practiced by groups rather than by individuals as a rule. It has been generally assumed that bird migration is an adaptation to avoid extremes of weather, and this is certainly one of the results of most migration habits.

The long distance record is held by the Arctic tern which nests in the summer inside the Arctic Circle, then flies down the eastern coast of Canada, across the Atlantic down the west coasts of Europe, and Africa, and finally ends up in the Antarctic region where it spends the northern winter months. This makes a yearly round trip of about 25,000 miles. These terns spend both winter and summer near the poles at the time when the sun never sets. This pattern of migration gives them maximum daylight at all time.

There has been considerable speculation about how birds find their way during migration. In some cases it appears that an older bird leads the way and follows landmarks along the way. Such birds will stop their flight when the weather becomes too overcast with clouds to permit them to follow these landmarks. There are some birds, however, which migrate thousands of miles over open water and find a small island. As there are no landmarks n open water it has been suggested that birds have a sense

organ which tells them their position by the magnetic field of the earth and the force brought about by the earth's rotations. Some migratory birds navigate by means of the position of the sun and stars. They make allowance for the changes in relative position of these through an internal time mechanism.

A population of green sea turtles live most of the year near the coast of Brazil, but each year the entire population begins to swim east across the Atlantic Ocean and end up in early April on Ascencion island, a small place about 1400 miles from the Brazilian coast. The island is only seven miles long, yet these turtles manage to reach it exactly without benefit of compasses or any navigational aid which man would require. After laying their eggs on the sandy beaches of the island, the turtles return to their Brazilian home. The young turtles which hatch out later have the inherited instinctive navigational ability to swim to the coast of Brazil, where they join their ancestors which they have never seen before.

Biological Clock (*Circadian Rhythm*)

For many years, it was thought that the daily rhythms exhibited by living things were the result of direct influences by the physical environment. For example chirping of crickets at nightfall and the singing of birds at sunrise. It was thought that the organism is totally dependent upon its environment. We now know that these organisms do not simply respond to environmental conditions, but contain within their system very accurate mechanisms for measuring time. In other words biological rhythms are innate. These are daily rhythms and so called 'circadian' from the Latin 'circa' meaning 'about' and 'dies' means 'day'.

Various animals manifest rhythmic behaviour as an innate behaviour. The fruit fly, Drosophila for example emerges from its pupal case and into adulthood normally at dawn.

Questions

1. What is behaviour ?
2. Name the different types of animal behaviour.
3. What is reflex action ? Give an example.
4. Give an example to show trial and error learning.
5. What is peck order ? Where do you find this ?
6. What is display ? What does this show ?
7. How do the seals take care of their young ones ?
8. What is migration ? Why do animals migrate ?
9. What is circadian rhythm ? Why is it called so ?

II. *Give reason :*

1. Conditioning is an acquired behaviour.
2. We see number of birds during winter in Ranganathittu.
3. Male birds upon choosing territory show off their feathers and dance in front of female.
4. Many animals live in groups.
5. Some animals produce pheromones.
6. Man is named *'Homo sapiens'*.
7. Some bees perform wagging dance.
8. Birds build nests.

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CHAPTER 10

Population and its Control

You are aware of the census taken in early 1981 when our population was counted. Census is taken about every ten years all over the world. Census provides the *demographer*, or the person who studies populations, the information with which he evaluates the characteristics of populations. How is population growing? What is its rate of change? What is the age and sex-wise distribution of the population and how is this going to affect future population? These are some of the questions for which the demographer seeks answers. Such information helps in planning for the future.

Trends in world population

Man was a nomadic hunter and gathered food for hundreds of thousands of years. During this period his

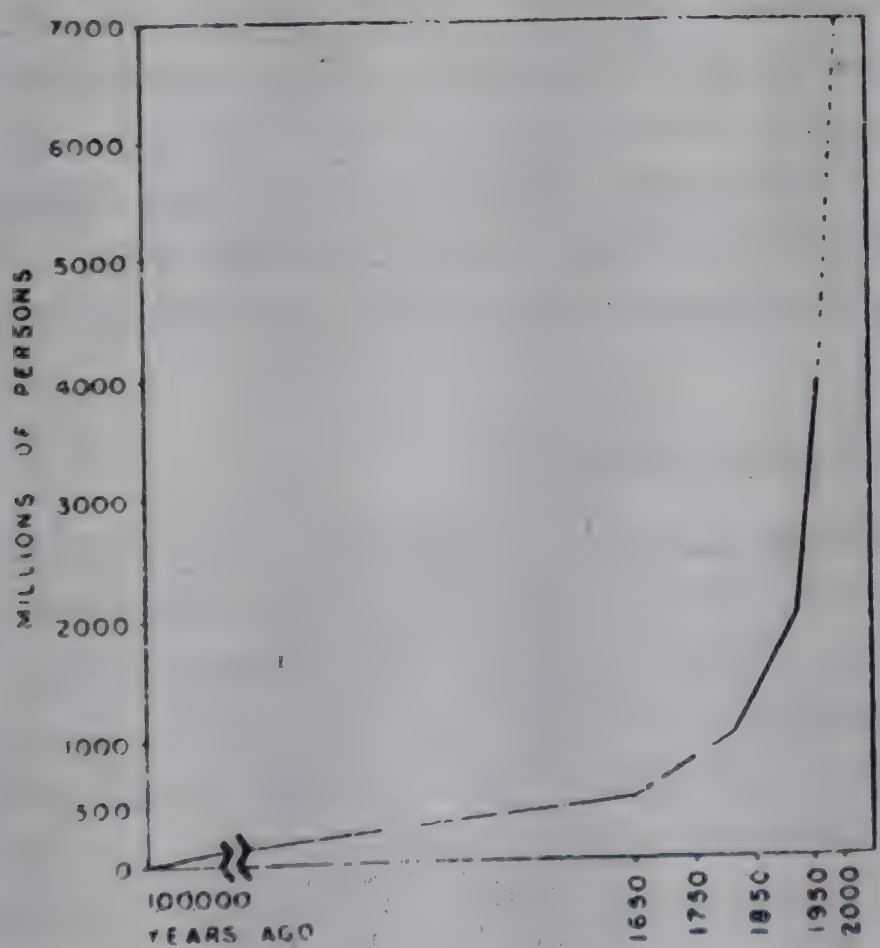

Fig. 10.1. World Human Population Growth Curve

population must have been quite small probably about ten million. About 10000 years ago, man learned to grow his own food. Raising plants and rearing animals made him establish permanent settlements. With more food available his numbers increased. Learning to make better implements with metals improved his agricultural technology and so also his food production. He spread out and in time was present in all the major continents, except for the Antarctic. By the year 1650, the world population was about 500 million (Fig. 10.1). In about 10000 years, human population appears to have increased 50 fold.

About this time (1650) the industrial and scientific revolution started. Even though there were periods of famine, epidemic diseases and war, world population doubled to 1000 million in just 170 years by 1820. It doubled again to 2000 million by 1930, in a period of 110 years. By 1975 it doubled to 4000 million in 45 years. At this rate of increase it is expected to be 7000 million by 2000 A.D. There were 40 people per square mile in 1930 ; by 2000 A.D. there will be 142.

Trends in Indian population

The trends in world population is reflected in India also. Next to China, India is the most populous country in the world. We have more than fifteen per cent of the world population in a land area less than $2\frac{1}{8}$ per cent of world's total land area. The present population of India is about 680 million (1981 census). It was 190 million in 1871, 251 million in 1921, 361 million in 1951, 548 million in 1971. At the present rate of increase our population will be over 1000 million by 2001. Since 1951 we

have added about 290 million to our population which is more than the entire population of the Soviet Union which has six times India's land area. The annual increase of 12 millions is only a little less than the entire population of Australia which is $2\frac{1}{2}$ times the size of India.

Nature of population growth

Suppose you take a bacterium which divides once in every 20 minutes and placed it in a flask containing nutrients for its growth, its population will double every 20 minutes as follows 2, 4, 8, 16, 32, 64.........in about 10

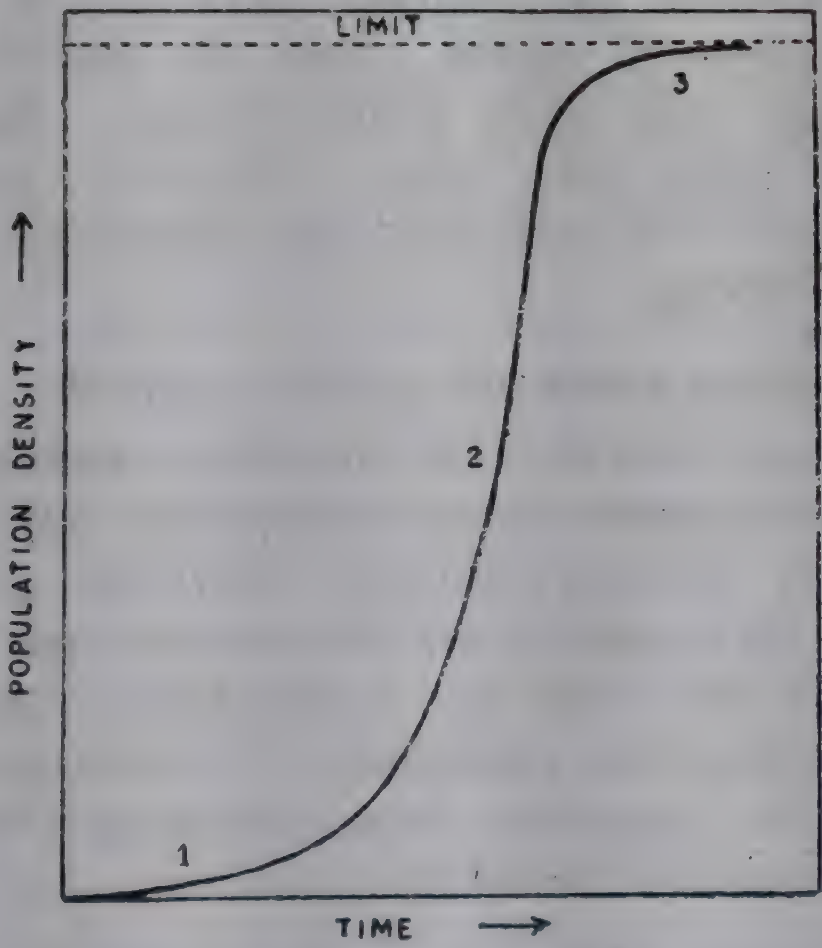

Fig. 10.2. Bacterial Population Growth Curve

1. First stage of slow population increase
2. Second stage of rapid population increase
3. Stage where environment checks population increase (limit of the environment)

hours (30 generations) the number will be about 1074 million. Soon the nutrients in the flask are used up and no more increase in number takes place. If a graph of the number of bacteria in the flask (population density) against time is made, you will obtain a *population growth curve* similar to that in Fig. 10.2. The curve rises slowly at first (stage 1), steeply in the second stage (stage 2) and finally when nutrients become less the curve flattens (stage 3).

Population growth of all organisms show a similar pattern. In the first two stages of population growth the process resembles the increase of money in a bank, attracting compound interest. Here the interest paid on the principal also starts getting interest. So money accumulates faster with time. Similarly, population increases faster with time since the offsprings also start producing offsprings.

Human population density and population growth

Population density is the number of individuals per unit area. Population density is controlled mainly by two factors, *birth rate* and *death rate*. *Birth rate* is normally expressed as the number of *live births* per year per thousand of population while *death rate* is the number of deaths per year per thousand of population. If birth rate exceeds death rate the population density increases. If they are equal the population density does not change.

To an extent population density in any place is also determined by people moving into the area (immigration) or people moving away (emigration) from it. In the past colonization of continents took place. Because of modern immigration laws, movement between countries is restricted.

However people moving within the country has led to increased population densities in various urban areas (cities and towns).

Human population explosion and its causes

You notice in Fig 10.1 that human population increased very slowly in the begining and then steeply in the past 350 years. The population doubling time, has reduced from 170 years (1650 to 1826) to 45 years (1930 to 1975). In the example of bacteria growing in the flask even with a constant doubling time, the curve rises in the second rapid phase of growth. In human population, with reducing doubling time the rate of increase is faster or accelerated. The accelerated rate of population increase is often called *population explosion.* It is as if the interest rate for the money in the bank attracting compound interest is continuously increasing with time.

The amount of nutrients set the limit for bacterial population in the flask. Even if nutrients are added space would soon limit growth. Eventually toxic waste produced by the bacteria would affect the increase in numbers. We can therefore expect that the earth's resources and area and the pollution caused by excess numbers will set the limit to human population growth.

What are the causes for the explosive growth of human population especially during this century ? The birth rate has not changed over many decades and even some decrease has occured. The real cause for the increased rate of population growth is a dramatic fall in death rate. Famines, diseases and wars used to take a heavy toll of human lives in the past. With improved food production, famine has not been a major cause of death. Wars reduce populations

only intermittently. The main check to population increase up to the 19th century was diseases. Death of the child (and often mother) at birth due to infection, malaria, small-pox, cholera, typhoid, plague, tuberculosis, influenza took their toll.

Improved sanitation, protection of water, use of insecticides, vaccination and other immunisation measures, antiseptic surgery, use of drugs and antibiotics have conquered all communicable diseases in the developed nations and reduced death rates considerably in many developing countries including India. Child mortality has decreased and life expectancy has doubled in the past 40 years leading to population explosion.

Consequences of Population Explosion

Scientific methods while decreasing death rate have also increased food production. The extra numbers have so far been fed without any major famine. However it cannot continue for long because of the limit of earth's resources and area. Besides, increase in numbers brings in many undesirable effects. Because of shortage of food, housing, drinking water and of almost anything required for a decent life, tensions, frustrations and uncertainty about the future in the form of unemployment increase. Antisocial elements take advantage of the shortages and malpractices begin in the proper distribution of the essential commodities needed for a decent life. This leads to reduced purchasing power of the common people, an unfair distribution of wealth and a greater disparity between the rich and poor. No government laws can effectively check antisocial activities in the presence of shortages just as no environment can provide resources for an ever increasing population. Population

increase has to be checked voluntarily by the people by controlling *birth rate.* Otherwise nature will take its course and check it by increasing *death rate.*

Family planning

Family planning means having children by choice. Because of our understanding of the biology of human reproduction we now have many devices by which conception (or fertilization) can be prevented. It is therefore possible not to have children when the parents do not want them. One way to prevent fertilization is to prevent the sperm meeting the ovum. A number of physical, chemical and surgical methods and devices are available today to prevent fertilization. For example the use of rubber sheaths by men (Nirodh) or rubber diaphragms by women prevent the sperm from entering the uterus.

You know that during pregnancy, ovulation does not take place. This is under the control of hormones. The *pill* taken orally by women only on certain days of the month, acts like the hormones produced during pregnancy and thereby prevents ovulation. It is taken in such a manner that the normal monthly menstrual cycle is not affected. Because of certain side effects in some women the pill has to be prescribed by the doctor.

Intrauterine devices (I. U. D.) in the form of small plastic loops or coils can be placed in the uterus (by a doctor). It prevents the implantation of the embryo in the lining of the uterus.

Surgical methods of cutting and tying the cut ends of the sperm ducts in man (vasectomy) or oviducts in women

(tubectomy) also prevents conception. A skilled surgeon can rejoin these tubes if need be at a later date.

Certain guidelines have been given for adoption by all married couples in order to make the family planning and welfare programmes a success. They are :

1. Not to have more than two children under any circumstance.
2. Not to produce children in response to religious, cultural or poltical demands.
3. No couple should assume that the small family norms are applicable only to the poor and the under privileged.
4. Those couples wishing to have more than two children should adopt children.

BIOLOGICAL CONTROL

Just as human population now, once in a while the population of some other species increase rapidly. This is mainly because the natural predators or parasites for the particular organism are not present in the environment. Man has been able to control successfully the spread of such organisms by introducing their natural enemies. This is called *biological control* where one organism is used to control another organism.

Biological Control of Cactus (Opuntia)

Cactus or prickly pear is a weed, that is a plant not wanted and in the wrong place. Some species of *Opuntia* were carried to Australia by man. They established and grew well in the dry climate there. However in the absence of natural pests it flourished fast in a few years and spread

rapidly. By 1925, an estimated 60 million acres were infested by cactus. Since mechanical and chemical control was too expensive to use, the eggs of a natural pest on it in Argentina, a moth called *Cactoblastis cactorum* was introduced. In a few years the larvae (caterpillar) of the moth multiplied rapidly, feeding on the cactus and brought the weed under check. (Fig. 10.3). The recovered land has

Fig. 10.3 The destruction of *Opuntia* by *Cactoblastis* in Australia
I. Healthy cactus plant. 2,3, Cactus partially destroyed by the larvae. 4. Complete destruction.

been useful for growing other plants. With the increase in insect population, it was for a while feared whether they would attack other plants when its natural food, the cactus, was used up. Fortunately the insect did not change its diet and their numbers came down. A similar method has been used in India to control another species of *Opuntia* by the cochineal insect.

Control of rodents-Rats and mice

Although there are many species of rodents in the world, two species have been associated with mankind for hundreds of years. These are the house rat and mice.

Although they may wander into the fields in warm weather, house rats and house mice tend to collect in homes, barns, and warehouses. House rats also find refuge in the sewage systems of large cities. These two rodent species eat all sorts of foods. They spoil more than they consume and they chew up various materials to make their nest.

So house rats and house mice are pests because of the destruction they bring about and also because they harbour the parasites of various diseases that they share with man. House rats, for instance, carry the germs of plague in their blood, fleas get the plague organisms from the rats, and then convey them to man. Rats and mice also contaminate food with their mouths, fur and waste materials. Where food is abundant, house rats and house mice produce several broods of young ones each year. Many cities have rat and mouse populations that outnumber the human population. People usually are not aware of this fact, for the rats and mice are often securely hidden during the daylight hours.

There are several methods to control rats and mice such as acute poisoning, baits, fumigants, repellants and environmental or biological control. Biological control includes (1) preventing reproduction or fertility, and (2) encouraging large populations of natural predators such as cats, dogs, mongoose, minks, foxes, hawks and owls. In some circumstances the most important control is to create an environment in which rats and mice cannot survive. This may be done by designing appropriate new buildings, repairing old structures, reducing harborage or improving sanitary conditions. In farm areas, snakes, predatory birds like certain hawks and owls and mammals like mongoose, foxes and cats kill the rats and mice.

Questions

I. 1. What is population explosion ? What are its causes ?

2. What is family planning ? Mention its methods.
3. What is biological control ?
4. Explain briefly how Cactus was controlled in Australia.
5. What are predators ? Give examples.
6. Mention the methods to control rats and mice.

II. Give reasons :

1. Amount of materials limit the growth of population.
2. Life expectancy has doubled.
3. Population increase has to be checked voluntarily.

Otherwise nature will take its course a
checked by increasing death rate

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FUNDAMENTAL DUTIES

51A. Fundamental Duties.—It shall be the duty of every citizen of India —

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem ;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom ;

(c) to uphold and protect the sovereignty, unity and integrity of India ;

(d) to defend the country and render national service when called upon to do so ;

(e) to promote hormony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities ; to renounce practices derogatory to the dignity of women ;

(f) to value and preserve the rich heritage of our composite culture ;

(g) to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures ;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform ;

(i) to safeguard public property and to abjure violence ;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement.

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